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# THE ENGINEERS' DIGEST

## REVIEW OF ENGINEERING PROGRESS ABROAD

*PRINCIPAL CONTENTS*

Stabilisation of Flow in Hydraulic Machines
Recent Developments of Cast Steel Alloys in Germany
Million Volt Industrial X-Ray Unit
Synthetic Materials and Climate
The 220,000 Volt System of the Hydro-Electric Power Commission of Ontario
The Forgeability of Metals
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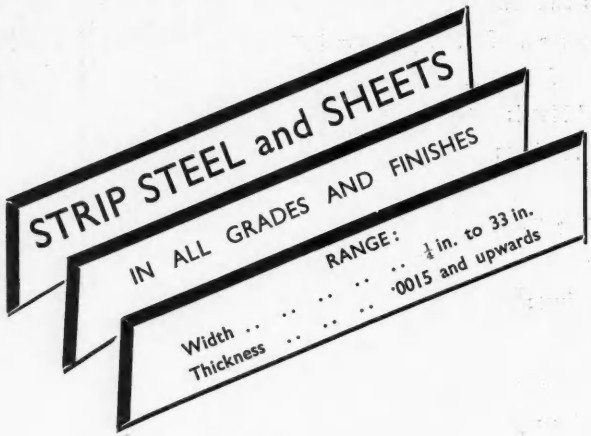


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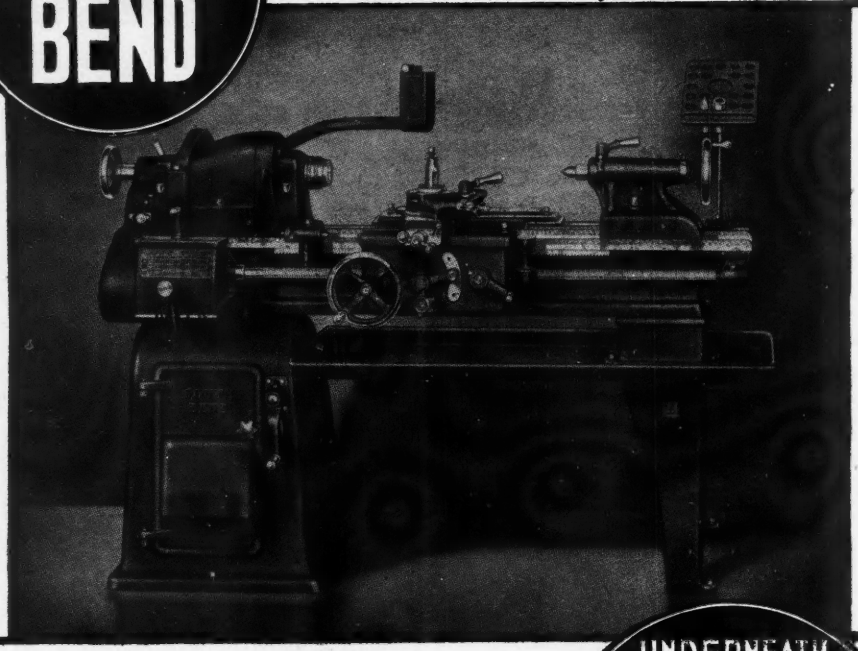

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*WHEN, in June, 1940, the first issue of this journal appeared, it was regarded, even by many people in the engineering profession, as a risky undertaking. The Representatives of our Engineering Institutes, some leading members of the Engineering Industries, and Civil Servants whose assistance in respect to our foreign relations we badly needed, have, however, recognised the vital necessity of our task. Their encouraging attitude towards us will always be remembered with deepest gratitude.*

*The excellent English technical press had far too little space to devote to the progress of scientific research and engineering practice abroad. We were already at war, and we were told again and again that this war is to be essentially mechanical and technical, that, in fact, it is to be an engineer's war. Thus it became obvious for us that the innumerable combinations of materials and new applications of knowledge, achieved in the laboratories and workshops of foreign countries, must be brought to the knowledge of our technical people.*

*This war is being fought to retain on the earth's face those ideals of social, political and religious liberty to which members of the British Empire have been accustomed for many generations. We have been anxious to take full part in this fight for a better world, and we thought that by publishing this journal we had found the place where our service might be of greatest value.*

*Now when going to press with the first number of the Third Volume of " The Engineers' Digest " we are proud and happy to state that our journal—in spite of the very modest means we had at disposal—has achieved a publicity which is beyond all our expectations. Leading engineering journals all over the world, including the Press Bulletin of the Air Ministry, have quoted " The Engineers' Digest " on many occasions. Thousands of engineering firms throughout the British Empire are making use of our services.*

*At present, engineering activities are devoted to war production. So is the entire production apparatus all over the world. Engineers, however, must think much further even in these days of strained efforts. They must think of the world after the war, of their share in planning the peace, a peace which shall secure economic and individual freedom to all, a peace free from unemployment, free from national hatred, and freed from the evils out of which wars arise.*

*We shall win the war and must win the peace, too. This journal is dedicated to these objectives. With all our heart we thank all those who, with their confidence and with their generous moral and material support, have been assisting us in our work.*

J. E. PAJZS.

# STABILISATION OF FLOW IN HYDRAULIC MACHINES

By PROF. JAN KIESWETTER. (From *Strojnicky Obzor, Prague*, Vol. 21, No. 7, April, 1941, pp. 105-113.)

FOR accurate governing of hydraulic turbines and centrifugal pumps, it is essential to stabilize the flow through the machine when working without interference from the governing gear. This stability of flow ensures an output truly corresponding to the position of the governor.

Two components of the flow must be considered, the *radial* flow velocity, $c_m$, and the tangential velocity, $c_u$, called the velocity of whirl. The water must be so guided in the machine as to have both these components stable, and at the same time, the flow should be in accordance with the original design of the machine.

The *radial* flow is guided by the (not necessarily volute) casing, the tangential flow, on the other hand, is directed by the blades in such a fashion as not to effect the *radial* flow. These two considerations should be treated separately.

For the turbines of low specific speed and relative velocity, simplified methods of calculation are sufficient. For high specific speeds and relative velocities closer consideration of all phenomena is necessary, and the flow must be divided into sections of equal discharge, their number increasing as the distribution of velocity across the cross-section becomes more irregular. These surfaces of revolution are called "main flow surfaces." It is of paramount importance to design the blades in such a fashion as to keep the flow within the main flow surfaces. If the flow can take place along two paths, one along the main surface and one along a secondary surface, the flow becomes unstable and its action upon the wheel becomes irregular. In practice this shows itself in a gradual drop of the developed power with fixed governor position. The decrease of power may amount to 1/3 of the full power and more. If now the discharge is first reduced by closing the guides, and is then increased again, the turbine developes once more full power.

This phenomenon has been observed occasionally in the Budejovice power station in Bohemia on three Francis turbines, each of 360 H.P., 125 r.p.m., 3.4 m head, 10 m³/sec. output and a sp. speed $n_s=500$, and also on a Francis turbine at the Horin lock of 31-37 H.P., 7.4-8.9 m head, 320 r.p.m. and $n_s=150$. Leading manufacturers of turbines and well-known experts have confirmed these observation, and pointed out the lack of knowledge on the occurrence and extent of these phenomena. Therefore, the author has attempted to explain this defect and to formulate means for its elimination.

Unstable flow may be caused by:

1. Detachment of flow from the walls of the pump casing, especially near the limit of cavitation.
2. Impurities in the water, fouling the inlet edges of the guide vanes and the blades.
3. Deposits on the blading surfaces.
4. Irregularities of flow in front of the guide inlet.
5. Local surcharges on the blades.
6. Unsuitable shape of the guides or of the blades, or their surface irregularity owing to impurities and deposits (2. and 3.).
7. Eddying in the suction tube of the turbine and in the discharge pipe immediately after the suction tube.

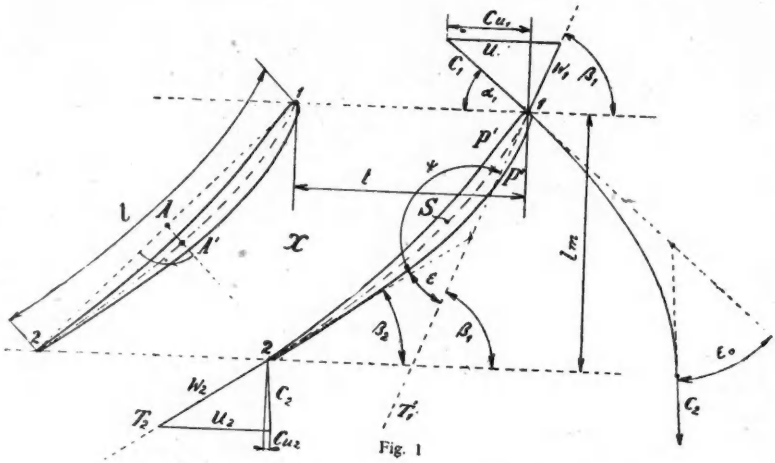


Fig. 1

Profiles of turbine blades in a cylindrical main flow surface.

According to the, as yet unfinished, research work carried out at the Czech Technical University at Brno, the real cause for instability is that with certain designs the flow has no rigid path through the impeller. Turbines with high specific speed, having straighter blades and smaller wheels are more sensitive to this phenomenon. In this article only a part of the problem will be considered—viz., the flow through the wheel.

The form of the flow space is determined by (a) the blade profile, (b) the position of the profile given by the angles $B_1$ and $B_2$, and (c) the relative position of the profiles, determined by the line x-y (see Figs. 6, 7 and 8).

To (a). The basis of the profile is its centre-line, S, (Fig. 1) characterised by the angle of efficiency $\Psi$, formed by the tangents at inlet and outlet, and lying in the impeller surface. If this surface is cylindrical the efficiency angle can be read off directly from the developed profile; if this is not the case, consideration must be given to the angle $\phi$ (Figs. 2 and 9) as follows: If the surface is inclined towards the wheel axis, $\phi$ is to be deduced from the apparent angle $\Psi_o$; in the case of a flow surface inclined away from the axis, $\phi$ is to be added to $\Psi_o$. The angle $\phi$ has no influence upon the energy of transformation. For any flow surface, we have

$$\Psi = 180° - B_1 + B_2$$

To (b). The position of the profile is given, in general, by the inlet and outlet angles $B_1$ and $B_2$, determined by the energy equation and the velocity triangles. The profile centre line is best determined from the length of the profile 1 or its axial height $l_m$ (Fig. 1). Present practice is to determine its shape between the points 1 and 2 by an arbitrary line, tangential to $w_1$ and $w_2$, but this method is inaccurate, but suffices for small pitches, t, as encountered with small and normal specific speeds. With high-speed machines the angle of curvature $\Psi$ must be taken smaller than $\Psi^+$, calculated from the water head by use of the main energy equation (Fig. 3). The amount of

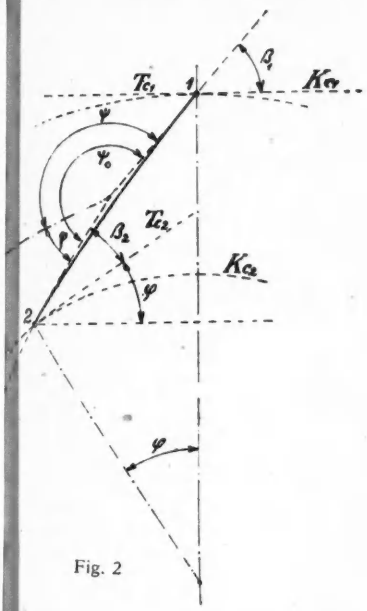


Fig. 2

esentation of the centre line 1—2 of a blade, posed from the main flow surface into the plan of the design showing the picturing angle.

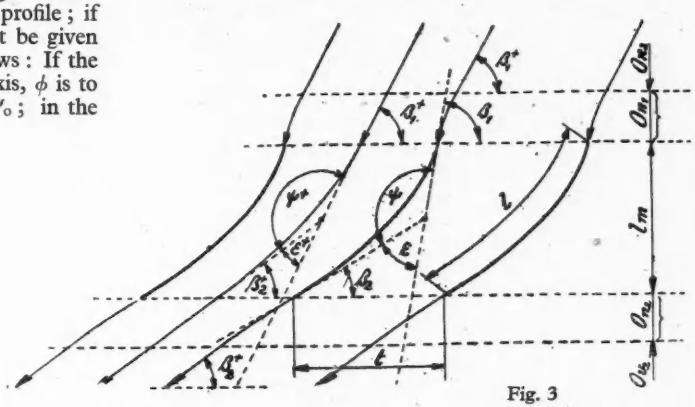


Fig. 3

The flow in a series of blades where l/t is small and the resulting efficiency angle $\Psi+$ is smaller than the real efficiency angle $\Psi$ of the blade.

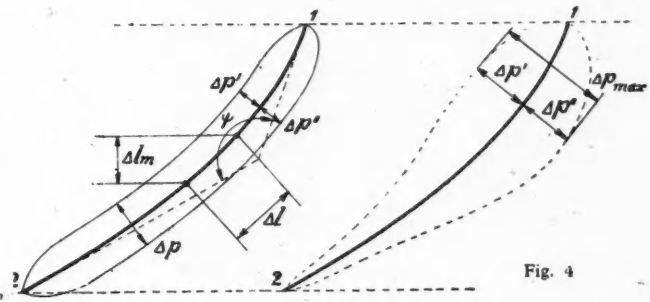


Fig. 4

Repartition of the driving pressure on the two surfaces of a blade.

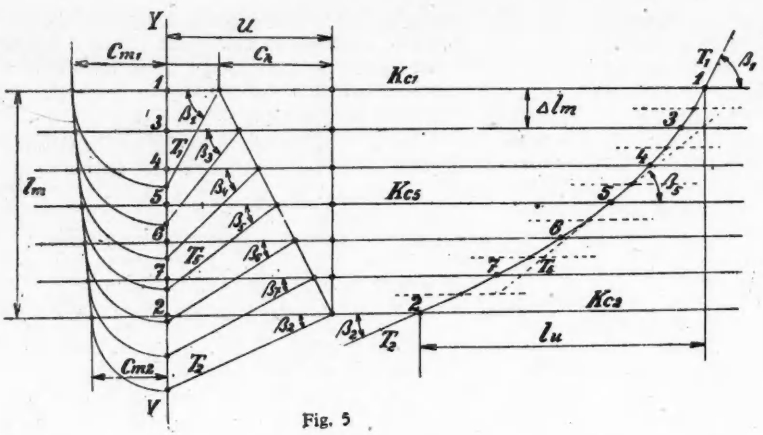


Fig. 5

Fig. 5

Designing the centre line in a cylindrical main flow surface for linear repartition of the driving component $C_h = C_{u1} - C_{u2}$.

this reduction may be found from theoretical consideration and can be confirmed by tests. $\Psi$ is called the "theoretical efficiency angle" as being different from the real one appearing on the two surfaces of a blade.

An exact method of tracing the centre line S is based on a consideration of the driving component $c_h$ of the circumferential velocity $c_u$.

$$c_h = c_{u1} - c_{u2}.$$

and of the pressures on the two blade surfaces; the "driving pressure" $\Delta p$ is the resulting pressure (Fig. 4). The shape of the centre line may be deduced from the desired resolution of the driving pressure along the blade. A simple graphical method for the case of constant pressure along the blade, and therefore, linear resolution of $c_h$ is given in Fig. 5, but other methods of resolution are also possible. Regarding stability, it is important to avoid local surcharges.

The real blade profile is then built up from the centre line, usually with half the blade thickness on each side.

To (c). Alignment of the profiles in order to obtain a surface is made along the line x-y with

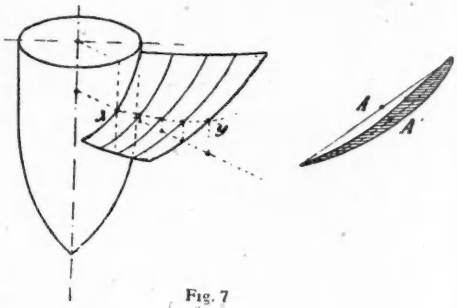


Fig. 7

Ranging the profiles along a ranging line x—y laying in a meridional plan and bent upwards.

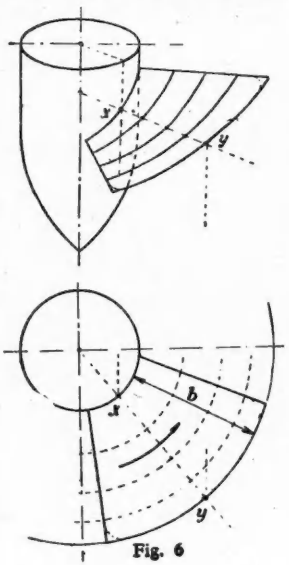


Fig. 6

Ranging the profiles along a radial ranging line x-y.

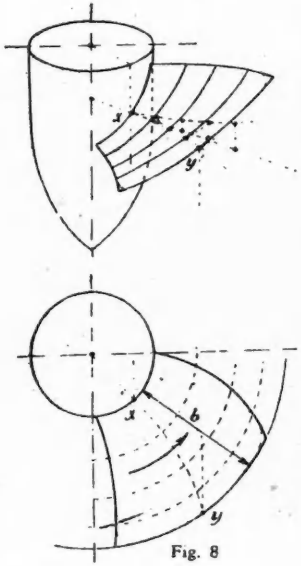


Fig. 8

Ranging the profiles along a ranging line x—y bent upwards and forwards.

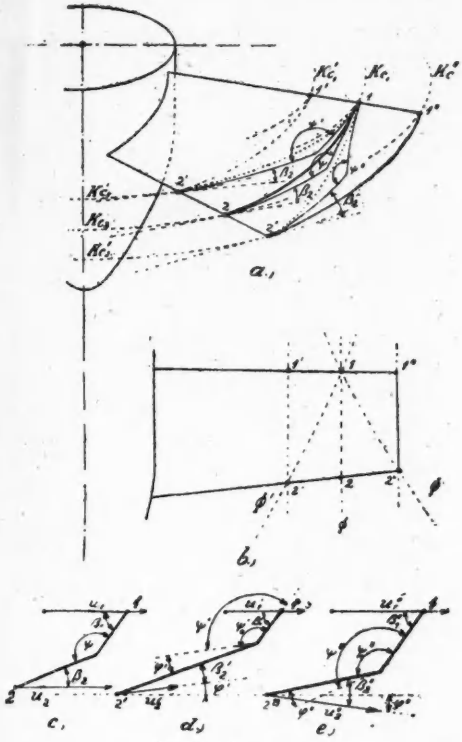

Fig 9

(a and b) Example of representing the efficiency angle $\Psi$ in a main flow surface $\Phi$ and the angles $\Psi$I and $\Psi$II in the secondary flow surfaces $\Phi$I and $\Phi$II; (c, d and e) representing the efficiency angles $\Psi$, $\Psi$I $\Psi$II in the surfaces $\Phi$, $\Phi$I and $\Phi$II by transposition into the plan of the picture.

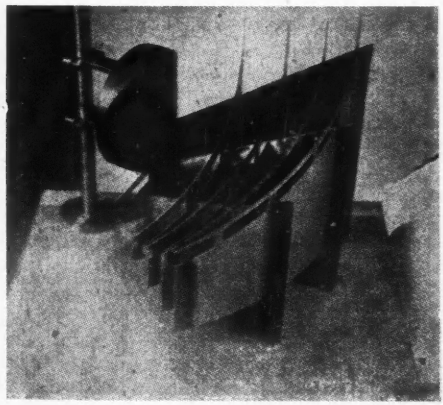

Fig. 10. Model for ranging profiles for an axial turbine.

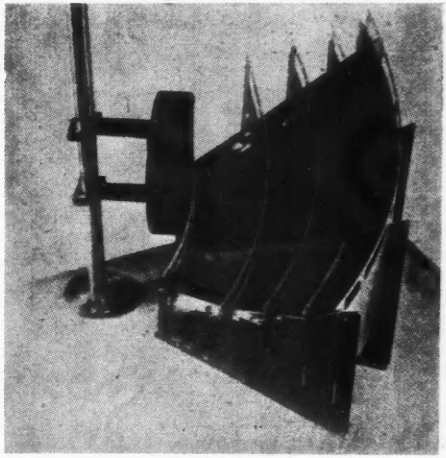

Fig. 11.
Model for ranging profiles for an axial turbine.

corresponding typical points of each profile on it. For this point either A or A' might be selected (Fig. 6) or any other typical point. The line x-y may be a radially or otherwise situated straight line (Fig. 7), or a curve in the meridional plan with bent upward ends, or a curve bent upward and backward (Fig. 8). The blade surface so designed must deviate the flow to obtain the energy transformation, but without the deviation of the flow out of the main flow surfaces. The correct shape of the line x-y assures that this requirement is fulfilled.

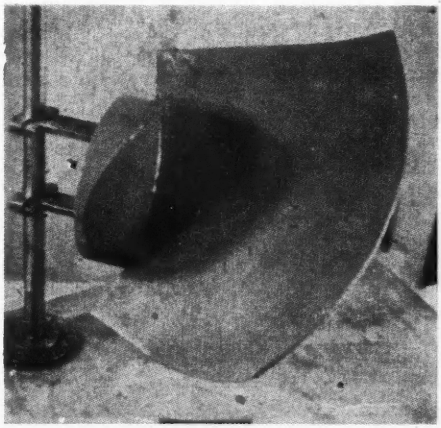

Fig. 12. Model of a stabilising blade for an axial turbine, which has proved to be efficient.

The author has found that the flow takes the path of least resistance, i.e., the path with minimum deviation from its original direction. For turbine blades we proceed in the following manner: After designing the blade, the possible secondary surfaces are estimated (Fig. 9) and it is determined whether their efficiency angle is adequately smaller than that of the correct one. If this is so, the blade surface is correct, if not, the blade design is altered by modifying the line x-y. The amount by which the efficiency angle of secondary surfaces must be smaller than that of the correct surface, depends on various factors, such as size of the wheel, possible changes in the direction of $c_1$, other disturbances, danger of cavitation.

This method of blade designing seems to be rather laborious at first, but the designer soon obtains an empirical procedure without the necessity of many modifications. In practice the arrangement of profiles can be greatly assisted by using models as shown in Figs. 11 and 13.

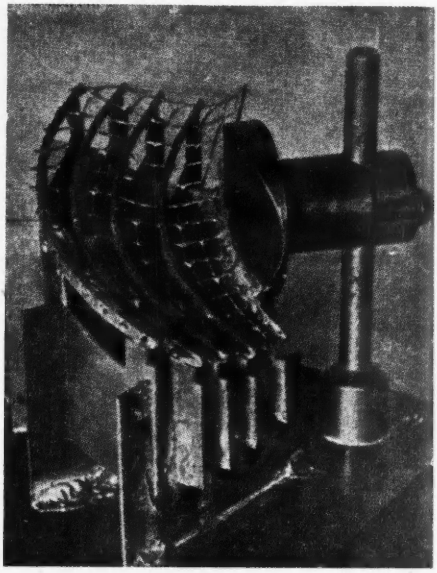

Fig. 13. Reinforcement grid for the model of a blade for an axial pump.

## THE FORGEABILITY OF METALS

By OWEN W. ELLIS. (From *The Engineering Journal*, Vol. 24, No. 10, October, 1941, pp. 466-475.)

IN the author's opinion, the words "forgeability" and "malleability" are synonymous. Malleability has been defined as "the property which permits a metal to be hammered or pressed into shape without cracking." In this definition the word "forgeability" could be substituted for the word "malleability." However, there might be some justification for the argument that malleability connotes hammering or pressing at room temperatures or not far removed from room temperature, while forgeability connotes hammering or pressing at elevated temperatures—temperatures above dull red heat.

On the question of forgeability or malleability the author has conducted numerous experiments, using a small drop hammer, the tup of which weighs about 113 lbs. Various methods of heating the samples have been employed, according to the place where the tests have been conducted and the temperatures to which the samples have been heated. Small changes in the weight of the tup can be produced by means of small lead weights.

The height of drop of the tup can be varied at will. The tup is allowed to fall freely, once it has been raised to the desired height for a given experiment. Every precaution is taken to ensure the free fall of the tup and care is exercised at all times to forge the test samples as quickly as possible after their removal from the furnace.

The results of a long series of tests on a straight carbon steel containing 0.4% of carbon are shown in Fig. 1. Here are six curves relating energy of blow to percentage reduction in height of a number of normal half-inch samples. It will be seen that the energy required to cause a certain percentage reduction in height of a standard sample will decrease with increasing temperature. For a blow of given energy the percentage reduction in height of a normal sample of this SAE 1040 steel increases more or less uniformly with increase in temperature. For example, with a blow of 400 ft.-lb. at the following temperatures the following approximate reductions in height were obtained with this steel:

| Temperature, deg.-C. | Reduction % |
|---|---|
| 584 | 31 |
| 674 | 37 |
| 754 | 44 |
| 847 | 52 |
| 927 | 58 |
| 1010 | 62 |

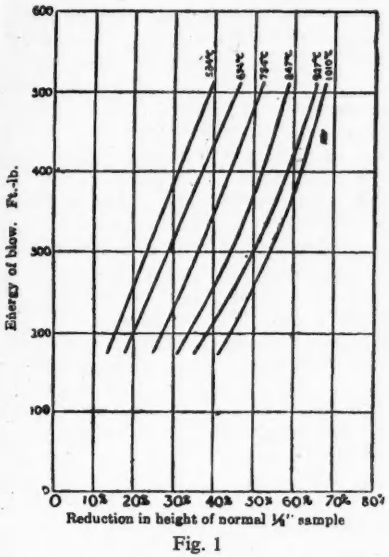


Fig. 1

Percentage reduction in height does not increase quite uniformly with temperature, since the critical points have an important effect upon the properties of steel. The influence of the A3 point on practically pure iron is particularly marked, as is demonstrated in Fig. 2, which shows the forgeability-temperature relationship of pure iron over the range 900-950 deg. C. within which lies the A3 point, shown to be in the vicinity of 915° C. in this particular series of tests. It will be seen that pure iron is actually more resistant to plastic deformation at temperatures just above the A3 point than at the A3 point itself. In fact, it does not become as forgeable as it is at the A3 point until it has been heated at least another 45° C. higher.

For all practical purposes, curves, like those

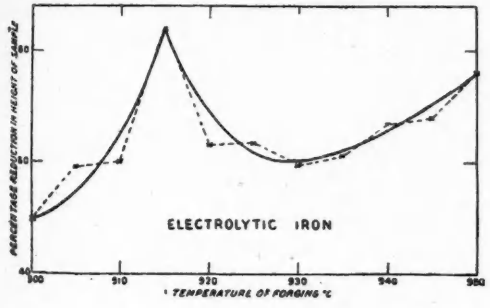


Fig. 2

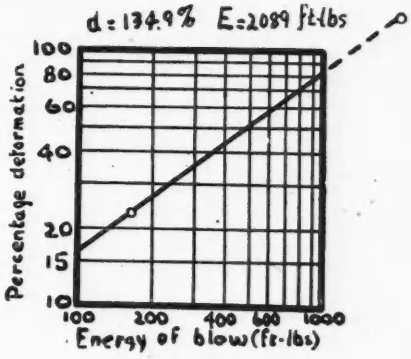


Fig. 3

in Fig. 1, can be represented by equations of the simple form

$$E = bD^n$$

where E represents the energy in ft.-lb. required to produce a percentage reduction in height D of a sample. What is rather more surprising is that the constants b and n in this equation are related one to the other, in the case of normal half-inch samples, by the simple formula

$$n = 1.56 - 0.47 \log b,$$

so that the equation

$$E = bD^{1.56 - 0.47 \log b}$$

gives the energy required to produce any percentage reduction of a sample if we know the energy needed to produce any one percentage deformation, say 30%.

This equation applies not only to steel, but also to copper, nickel, lead and probably alum-

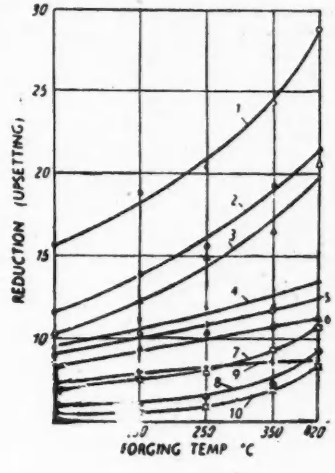


Fig. 4

inium. And furthermore, it can be used in connection with samples of shapes other than normal cylinders; shapes for example, such as cones or frusta.

Main, an English metallurgist, when discussing the paper in which the author first brought forward this equation, pointed out that it could be re-written in the form

$$3.32\text{—}\log E = a\,(2.13\text{—}\log D)$$

where $a = 1.56\text{—}0.47 \log b$.

Now it can readily be seen that, when log D=2.13, the right hand side of the new equation becomes zero, so that

$$3.32\text{—}\log E = 0.$$

Hence when log D=2.13 or D=134.9%, log E=3.32 or E=2089 ft.-lb.

It is manifestly impossible to reduce the height of a sample, no matter what its form, by 134.9%, so that the conditions described above are imaginary only. But, given this information, such a graph can be drawn as that in Fig. 3, which is one of the innumerable straight lines which could be drawn through the point corresponding to D=134.9% and E=2089 ft.-lb. In this figure percentage reduction is plotted on logarithm paper against energy of blow. Suppose now that a few experiments on a single blow drop test machine have proved that a blow of 170 ft.-lb. will produce a percentage deformation of 23 in a normal half-inch sample of steel of known volume at 1850 deg. F., all that is necessary to find out the energy to produce other percentage deformation in samples of the same material having the same size and shape and formed at the same temperature is to join the point in Fig. 3 corresponding to E=170 and D=23 to the point corresponding to E=2089 and D=134.9 by a straight line and the points on the straight line so obtained will provide all the desired information.

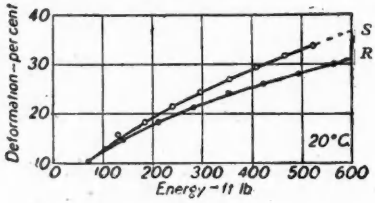


Fig. 5

There is a well-known law known as Tresca's theorem which states that the amount of energy required to produce analogous changes of shape in geometrically similar bodies is proportioned to the volumes or weights of the bodies concerned.

Now what might be called the fundamental diagram (Fig. 3) for normal half-inch samples can be usefully employed in estimating the energy required to deform smaller or larger samples. Obviously this can be done with the aid of the diagram by applying the law of proportionality. As an example it is desired to calculate the energy required to reduce a normal three-inch cylinder of steel by 70% of its height in a single blow at a temperature of 1850° F. From the experiment we have found that 170 ft.-lb. of energy will reduce the height of a normal half-inch cylinder of this steel by 23%, and using the graph 800 ft.-lb. are needed for a 70% reduction of the same specimen at the same temperature. Thus by Tresca's theorem for the three-inch cylinder the energy required becomes:

$$\frac{800 \times \text{volume of 3-in. cylinder}}{\text{volume of } \frac{1}{2} \text{ in. cylinder}} = 57{,}600 \text{ ft.-lb.}$$

It is not likely that the result thus obtained will be mathematically exact. The order of magnitude, however, will be correct.

Comparison with some actual figures may be of interest. In a paper by Zeerleder, published in 1937, he reproduced the series of curves which are given in Fig. 4. Consideration of curve 5 in this graph shows that the aluminium-copper-magnesium alloy, Avional D, is reduced about 15% in height at a temperature of 420° C under a single blow of 70 ft.-lb., this having been the energy of the blow used in all the experiments referred to in this graph. The samples in these experiments were normal 20 mm. cylinders. It is somewhat remarkable that the point corresponding to E=79 and d=15 lies very close to, if not on, the straight line which was drawn in the fundamental diagram for half-inch normal samples, from which one might guess, but only guess, that the energy of the single blow required to reduce a normal 20 mm. (0.79") cylinder of Avional D by about 18.5% would be about 120 ft.-lb. Zeerleder's paper shows that a normal 80 mm. cylinder of Avional D is reduced by 18.5% by five blows of 1950 ft.-lb. capacity. Our very rough estimate of the energy of the single blow required to reduce such an 80 mm. cylinder would be 7,680 ft.-lb.

The actual energy absorbed in reducing the cylinder in five blows was 5x1950=9750 ft.-lb.

In the same paper Zeerleder shows that a similar cylinder of Avional D is reduced 36% by ten blows each of 1950 ft.-lb. Reference to the fundamental graph shows that a single blow of 310 ft.-lb. would reduce a 20 mm. cylinder of

Avional D by 36% of its height. Our estimate of the energy of a single blow required to reduce an 80 mm. cylinder of Avional D would then be $310 \times 64 = 19{,}840$ ft.-lb. The actual energy absorbed in reducing the 80 mm. cylinder in ten blows was $10 \times 1950 = 19{,}500$ ft.-lb.

Not too much stress should be placed on the fact that these estimates lie as close as they do to the experimental results, because when metals or alloys are forged at temperatures at which the hardening effects of plastic deformation are immediately effaced by recrystallisation, the energy absorbed in their deformation by a single blow may be considerably greater than that absorbed in producing the same deformation by a number of blows. Further, it must also be remembered that the fundamental diagram of Fig. 3 applies to normal half-inch samples, and not, as far as is known at present, to normal 0.79 inch samples.

Thus it might be expected that the estimates of the energy required to deform Avional D with a single blow would have yielded results somewhat higher than those obtained in Zeerleder's experiments with a number of blows. This may be illustrated by means of the two following diagrams which show the results of single and multiple-blow drop tests on normal three-quarter-inch cylinders of annealed copper having a Brinell hardness at room temperature of 11.5. Fig. 5 comprises two curves, one showing the relationship between deformation and energy of single blows of varying energy content (curve S), and the other showing the relationship between deformation and the total energy of repeated blows of equal content, i.e., 70.6 ft.-lb. (curve R). All these were made at room temperature. A comparison of curves S and R brings out the interesting fact that, at room temperature, more energy is absorbed in forging a sample of copper in a number of blows than in a single blow, or, conversely, a greater change in shape is produced by a single blow of given energy than is produced by a number of blows of the same total energy.

Curves for the tests at 200° C are particularly interesting because they coincide in those parts which refer to the tests with blows of low energy (up to about 300 ft.-lb.) but separate in those parts referring to the tests with blows of higher energy. As is well known, the greater the degree of plastic deformation the lower is the temperature of recrystallization, and, since blows of high energy produce more flow than blows of low energy, it is not surprising that the curves for single and repeated blows do not coincide over their entire lengths, but tend to separate in those parts which refer to high degrees of plastic deformation or energies of blow. Curves for forging temperatures of 250° C and 400° C which demonstrate the points just discussed, are shown in Fig. 6.

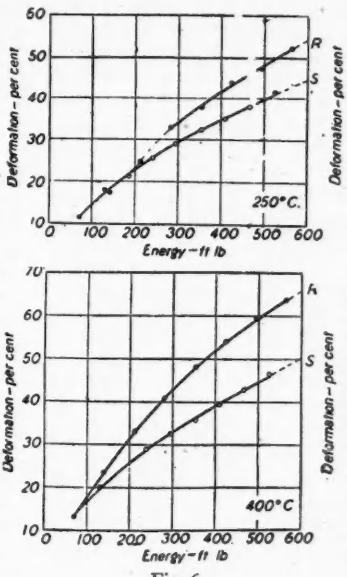

Fig. 6

At forging temperatures of 400° C and higher, the single and multiple-blow curves separate again, the former now always lying below the latter. Now, these relatively high forging temperatures are temperatures at which the hardening effects of forging are likely to be immediately effaced by recrystallization of the metal being forged. It can be said, therefore, that, at temperatures at which the hardening effects of plastic deformation are immediately effaced by recrystallization, the energy absorbed in deforming a metallic body by a single blow may be greater than that absorbed in producing the same deformation by a number of blows. The converse proposition is, of course, true, as reconsideration of the curves shown in Fig. 5 will show.

Fig. 7 shows two useful curves which enable rough estimates to be made of the energy, other things being equal, required to produce equivalent

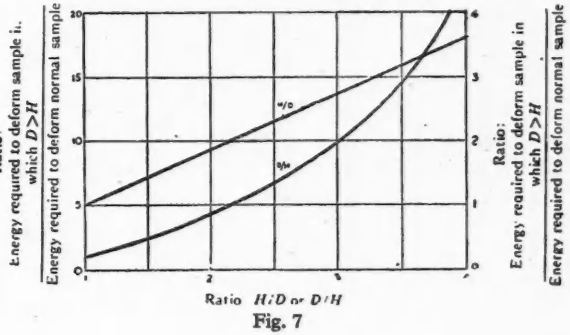

Fig. 7

reductions in height in cylindrical samples whose heights are greater or less than their diameters, given the energy required to produce a given reduction in height in a normal sample. The curve marked H/D refers to cylindrical samples whose heights are greater than their diameters, that marked D/H refers to samples whose diameters are greater than their heights. If we know the energy required to produce a 25% reduction in height of a normal cylinder of known analysis and state, and it is desired to estimate the energy required to obtain a similar reduction in height in a cylinder of similar analysis and state whose height is three times its diameter, we first find the point of intersection of the ordinate marked 3 and the curve marked H/D, and then connect this point by an abscissa to the right hand side of the diagram. This gives the value $\pm 2.75$; that is, about $2\frac{3}{4}$ times the energy needed to deform a normal cylinder would be required to deform a cylinder three times as high. On joining the point of intersection of the ordinate marked 3 and the curve D/H by an abscissa to the left hand side of the diagram, the value $\pm 10.0$ is obtained, indicating that about ten times the energy required to deform a normal cylinder would be required to deform a cylinder three times as wide.

It has been already mentioned that the critical points have an important effect upon the properties of steel. Fig. 8 shows not only the importance of the critical points upon the forgeability of a group of straight carbon steels, but demonstrates (1) the marked effect of carbon,

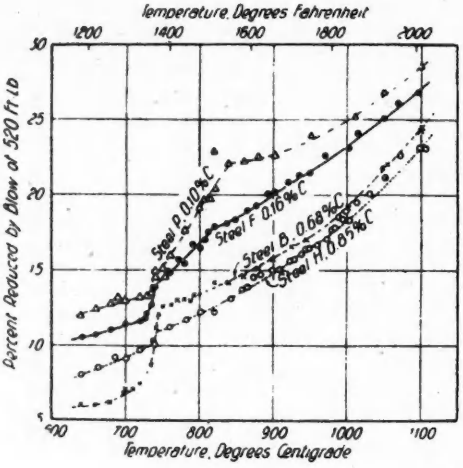


Fig. 8

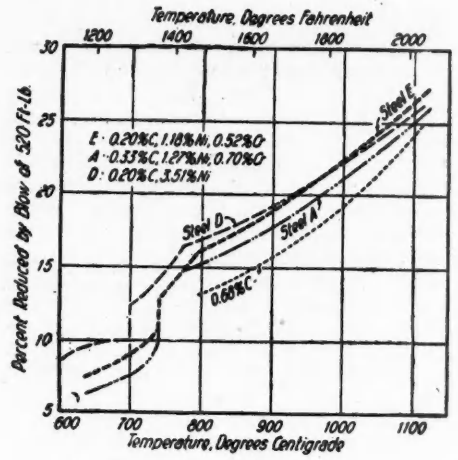


Fig. 9

and (2) the influence of structure, on the forgeability of steel. At temperatures above the A1 point (735° C) the 0.16% carbon steel is easier to forge than either the 0.68% or the 0.85% carbon steel, as might be expected. It is surprising to note, however, that below A1, the particular 0.68% carbon steel chosen for test was harder than the eutectoid steel with which it was compared. This can be accounted for only by assuming that the structure of the former was such as to make it harder than the latter. In all the experiments the times of heating the samples, which were cut from bars "as rolled," were sufficient to ensure that they were uniformly heated throughout, but certainly not long enough to bring the steels to equilibrium.

Fig. 9 makes possible a comparison between steel SAE 2320 (nickel) and steels SAE 3120 and 3130 (nickel-chromium). Note should be made of the preponderant effect of carbon upon the forgeability of these steels.

Of recent years much has been heard of the high-yield low-alloy steels. Fig. 10 deals with Cor-Ten, a steel containing about 0.10% C, 0.3% Mn, 0.8% Si, 0.45% Cu, 1.0% Cr, and 0.15% P. The yield point of this steel is in the neighbourhood of 62,500 lb./sq. in., as compared with 45,000 lb./sq. in. for straight carbon steel of the same carbon content. The forgeability of Cor-Ten is distinctly lower than that of SAE 1010, forgeability-temperature curves for two types of which are shown in this graph. These curves, it will be observed, differ quite materially from one another over the range 735° C. This

can be accounted for by the marked difference in structure between the two steels. Steel P, which had a very low silicon content, showed considerable banding and relatively large grain size in the ferritic areas, while the other SAE 1020 steel had a uniform structure and relatively small grain size.

Man-Ten is a typical SAE T1330 steel and can be compared with SAE 1030, as is done in the Fig. 11. There is little to chose between the two steels as far as forgeability is concerned. It is of interest to record that the forgeability-temperature curves for Man-Ten and a carbon steel of approximately the same tensile strength at room temperature, viz., a SAE 1040 steel, correspond closely to one another over the entire range 600° C to 1200° C.

It may be asked why some of the curves in the figures intersect one another. One reason may be this: The grain sizes of these steels vary relative to one another at different temperatures. At a temperature where the grain sizes of the steels are almost identical the lines intersect one another. This emphasises how much more important are the effects of austenite grain size than inherent grain size on the forgeability of steel.

Speaking generally, the technique of forging aluminium and its alloys at their relatively low forging temperatures, 360° C to 510° C is much the same as that of forging the heavy metals and their alloys at the relatively high forging temperatures. The alloys of magnesium, however, present a problem all their own; they verge on "hot shortness." In other words, they lack cohesion under stress at high temperatures. On

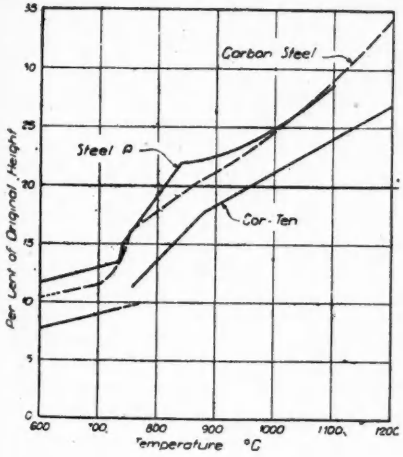


Fig. 10

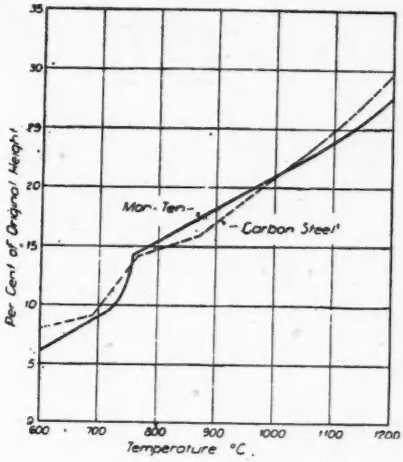


Fig. 11

this account they are extremely difficult to roll and to forge as cast, though they are less susceptible to rupture when forged after extrusion, owing to the consolidating effect of extrusion. Temperature and the rate of deformation of this alloy, too, have profound influence on their forgeability.

The sensitivity of ultra-light alloys requires that a special technique be adopted in their treatment. Before they can be forged under the drop hammer, or even the screw press, it is often desirable to consolidate them by free forging or under a hydraulic press, since slow rates of deformation are imperative in the early stages of forging.

In free forging it is essential that the blows be so controlled and directed as to guide, rather than to force, the material into the desired shape. Work must be applied to ultra-light alloys with the utmost uniformity. The hot material must be rotated and reciprocated after each blow. Surfaces should be forged slightly concave rather than flat.

The later forging operations should be performed at successively lower temperatures than the first, so as to avoid excessive grain growth at all stages in the formation of the parts. In order to retain as fine a grain as possible, they should be quenched in water immediately after forging. Fine grain size counteracts the directional effects of the fibre induced in the alloy by forging; further it promotes homogeneity of structure and so facilitates the heat treatment of the finished forgings.

Magnesium and its alloys are prone to grain growth on reheating. Hence great care must be exercised in the reheating of components which have been forged at temperatures below the recrystallization temperature.

The rates of deformation of the ultra-light alloys should always be lower for equal weights and higher for equal volumes of material than those used in the forging of heavy metals. Rolled, extruded or forged stock can be treated with somewhat less consideration than cast material, forging under the screw press or the drop hammer can be considered without fear.

When die-forging under the drop hammer, the rate of deformation is not so readily controlled as in free forging or in press-forging. A definite relationship should, therefore, be maintained between the size of the part being forged and that of the hammer employed.

The pre-heating time for dies to be used in forging light alloys of aluminium and magnesium may be shorter than that for dies to be used with heavy material, owing to the lower temperatures involved and to their usually smaller size and lighter weight.

The choice of the method to be employed in the production of a component is one of considerable importance. Due regard has to be given to the equipment available, then to the forgeability of the alloy to be used, and, lastly, to the design of the component itself. There must also be borne in mind the fact that the change in shape produced by pressure may, even will, differ markedly from that produced by impact.

## RECENT DEVELOPMENT OF CAST STEEL ALLOYS IN GERMANY

By H. L. KORSCHAN. (From *Die Giesserei*, Vol. 28, No. 5, July 25th, 1941, page 325 and continued.)

THE shortage of certain raw materials in Germany, metals in particular, is the dominant factor governing the development of cast steel alloys, with two aims in view, to replace certain constituents in alloys by other metals available in greater quantities, and eliminate altogether some classes of alloys in applications where their use was formerly considered as pertinent and imperative. These problems brought about a number of changes in the production and application of alloy steel castings, which will be covered in this article.

### LOW-ALLOY CAST STEELS.

**Silicon Steels.** The foremost importance of silicon steel lies in its high wear resistance and provides, therefore, an excellent material for gear wheels, bevel wheels, etc. The hardness of a 1.5% Si steel can be regulated by varying the carbon content between 0.4 and 0.75%. Fig. 1 shows the *frequency* curves of a steel alloy containing 0.4%-0.45% C, 0.5-0.7% Mn, and 1.5% Si. 1.5% Si steels with lower carbon content found no application, but 0.05-0.08% C and 3.5-4.2% Si gives the steel specific magnetic properties, making it a valuable material for the smaller parts of magnetic testing machines.

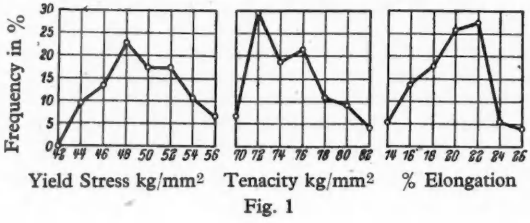

Fig. 1

Although additions of Mn or Mo would provide a means of widening the field of application of Si-steels, recent practice dispenses with these alloying elements, and 1.5% Si high carbon content steels are being used instead, owing to the shortage in raw materials.

**Manganese Steels.** Compared with ordinary carbon steels, addition of manganese contributes to greater tenacity, higher limit of ductility (high yield) while it reduces the percentage elongation of the alloy only slightly. It is, therefore, particularly suited for a great variety of machine components. As manganese is available in considerable quantities in Germany, it forms an important substitute for Nickel and Chrom-Nickel steels. The usual composition of Mn-Steels is: 0.2-0.45% C, 1.2-1.7% Mn, but not more than 0.4% Si. As with Si-steels, Mn-steels can be made wear resistant, and for such use the composition is 1% Mn and 0.45-0.5% C.

**Nickel Steels.** That Nickel, as an alloying element, played a most prominent part in metallurgical progress, can be attributed to its excellent hardening properties and to its beneficial effect of lowering the transformation point of steels. These properties of Nickel are of particular importance for castings having heavy sections and complicated shapes, as in such instances a faster cooling medium than air could not be tolerated. To do justice, however, it must be admitted that in some cases the importance of Nickel was over-

estimated, as for instance it is erroneous to assume that 2% Ni is capable of preventing the formation of cracks and other casting defects.

Recently, endeavours have been made to eliminate Nickel as far as possible; 2% Ni-steel is not being specified any more in Germany, its place being taken by Manganese and Chrom-Molybdenum steels. In other applications pure steel is used in place of Ni-steel, since by arranging a suitable melting temperature and correct heat treatment, a steel of 0.23% C, 0.43% Si, and 0.60% Mn shows the following strength figures.

| Stress at Yield kg/mm² | Tenacity kg/mm² | Elong. % | Con-traction % | Notch-shock Strength mkg/mm² |
|---|---|---|---|---|
| 27.4 | 46 | 36.4 | 61 | 10.1 |

Considering the tenacity, the high yield and % elongation are especially noteworthy in the above table. It must be borne in mind, however, that such properties can be achieved only at the expense of extremely careful manufacturing processes.

Naturally the use of 3-5% Ni-steel alloys has also been substantially restricted.

**Chrome Steels.** Their use is justified by the hardening and wear resisting effect of Chromium in steels, and is fully utilized to-day. Their application includes crane parts exposed to wear, runners for centrifugal sludge pumps, etc. Higher Cr.-steels are used for castings demanding heat and corrosion resistance. The tendency to casting cracks at sharp changes of section can be overcome by the provision of generous fillets and careful casting technique.

**Chrome-Nickel Steels.** The combination of these two alloying elements has created a most important type of alloy for highly stressed constructions. A marked improvement of the strength properties of this alloy is obtained by additions of further alloying elements, such as Molybdenum, Vanadium, Tungsten. Substitutes for this class of alloy were needed in Germany, and as such, Cr-Mo and Cr-Si-Mn steels proved to be the best, but it must be remembered that Mo, too, is scarce in Germany.

The following table gives the average composition and strength figures of a Cr-Ni-Mo steel and of a substitute, e.g., Cr-Si-Mn steel contraction.

| C % | Si % | Mn % | Ni % | Cr % | Mo % | Tenacity kg/mm² | Yield kg/mm² | Elong. % | Con-traction % |
|---|---|---|---|---|---|---|---|---|---|
| Cr-Ni-Mo-Steel— | | | | | | | | | |
| 0.30 | 0.30 | 0.40 | 1.0 | 0.9 | 0.2 | 73.3 | 53.8 | 18.3 | 51 |
| Cr-Si-Mn Steel— | | | | | | | | | |
| 0.40 | 0.55 | 1.20 | — | 1.1 | — | 84.5 | 66.6 | 16.5 | 47 |

Other substitute alloys, as Cr-Va, Cr-Mn, Cr-Mn-Va and Cr-Mn-Mo have found less frequent application for castings than for forgings and rolled sections.

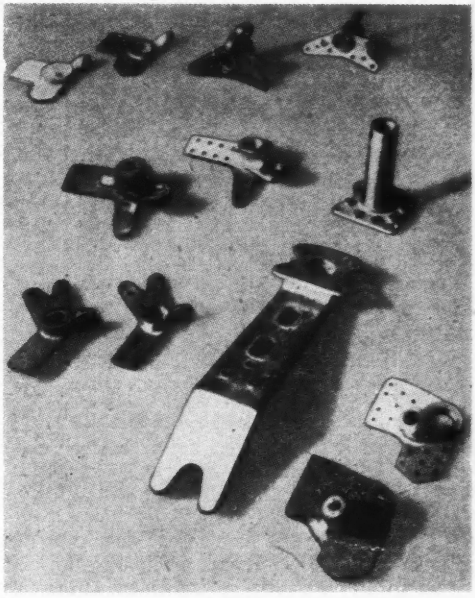

Fig. 2

**Molybdenum, respectively Cr-Mo Steel.** Progress in the aircraft industry necessitated a high quality cast steel alloy for engine components and for gussetts (Fig. 2). These often complicated and thin section articles are fabricated from Cr-Mo steel. The most important specification for this alloy is, apart from ductility, good weldeability; moreover it must have great endurance strength as the stressing is dynamic as is the temperature to which it is exposed during operation. For the various applications, the aircraft industry specifies two sets of strength figures which are obtained by means of respective annealing of the same alloy. Fig. 3 shows the actual and the specified strength-frequency curves based on examining 100 articles in each case.

With these few examples, the field of application of Cr-Mo steels is, of course, by far not covered. The heat resistance property of Molybdenum, namely to maintain the strength of steels at elevated temperatures, forms the basis of its adoption for heat resistant applications (up to about 550° C). When the stressing is moderate Mo-steel, when it is large the Cr-Mo variety of steel alloy is being used. Fig. 4 shows the heat resistance of Mo and Cr-Mo steels up to 500° C. It can be seen that in both cases the physical

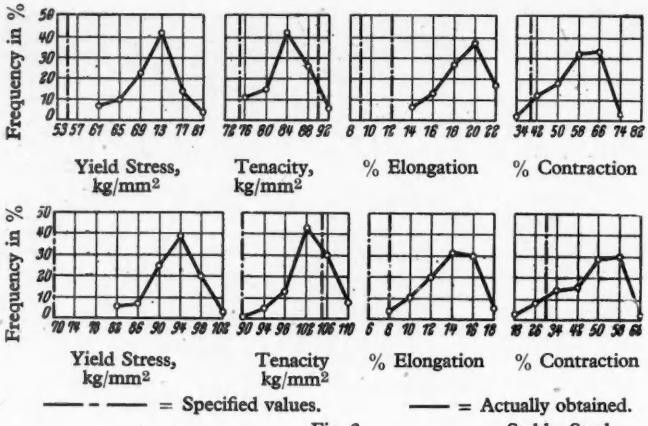


Fig. 3

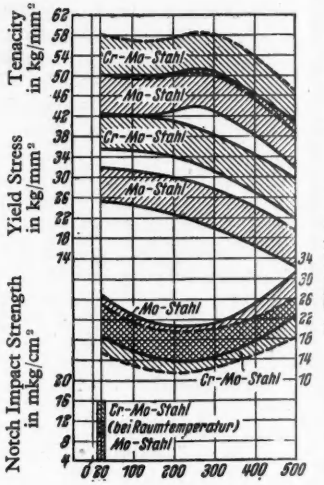


Fig. 4

strength properties of steel are maintained up to about 250-300° C respectively, while at 350 and 450° C respectively the figures are still at least as high as that of a 45.81 steel.

Having arrived at such an excellent cast steel, in many applications it was possible to use castings in place of forgings. The following practical example illustrates the advantages of this method. For a Siemens radial turbine of an output of 18-20,000 KVA, the forged turbine casing was of Cr-Mo steel with a specified strength figure of 50 kg/cm². To reduce manufacturing costs and time, it was decided to use cast casing instead, similarly of Cr-Mo steel. To allow for the inferiority of the casting compared with the forging, the minimum strength of the steel was now specified as 70 kg/cm². When put into service the casting disclosed such excellent qualities, that shortly afterwards the specified strength of the steel was reduced to 50 kg/cm² and even so the result was better than with the previously used forged casing. The condition for such successful employment of castings is that the article should present no difficulties from the point of view of casting technique. It might be mentioned that casting facilitates the design of the article and in all a considerable saving in costs and time can be effected. In addition a particularly favorable point for Cr-Mo and Mo-steels is their excellent welding properties.

Economy in Molybdenum instituted in this case too, endeavours to find substitute alloys for heat resistant steels. Fig. 5 shows the heat resistant properties and the yield point at high temperatures of Cr-Mo and Mo steels respectively (A and D) between 100 and 400° C. For the sake of comparison similar figures for plain carbon Stahl = Steel, bei Raum temperature = at room temperature.

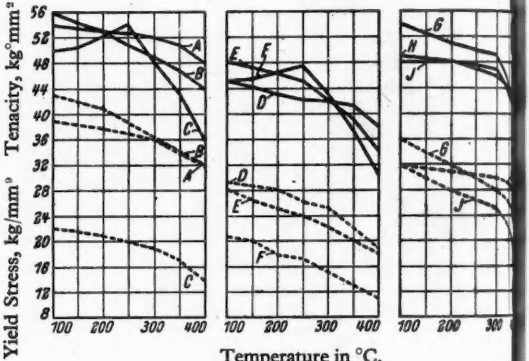


Fig. 5

(C and F) are also shown on the graph. The corresponding figures of two substitute materials are given by lines B and E, representing Cr-Mn and Cr-Va steels respectively. Below 400° and for lower stressing Mn-Si steel (J) can also be used.

## HIGH ALLOY CAST STEELS.

**Cast Steel Alloys of Special Mechanical Properties.** Manganese steels are still used to the best advantage in applications exposed to large wear due to pressure and impact; this alloy, namely, improves the strength properties during cold working and in this way offers great resistance to wear. But it must be also emphasised that a 12% Mn steel is not superior to other alloys when the wear is caused by friction, carbon

or low alloy steels are quite sufficient in such cases.

Another special high alloy steel contains 1% C, 9% Cr and 3% W and is used for safes and other strong room equipments, as a fire resisting material. By adopting certain constructional precautions, safety against fire and forcing of the safes can be obtained without the use of this alloy. Thus for fire protection a low alloy material, of good heat conductivity, might be used and for additional safety of forcing the safe, alternate layers of hardened steel and concrete is recommended.

It is not unusual in Germany to fabricate even high quality tools from so called substitute materials.

**Cast Steel Alloys of Special Chemical Properties.** Considerable progress marks the first, and pump parts, valves, etc., are almost invariable fabricated from alloys 5 and 6 nowadays. The addition of 2% Mo in alloy 6 increases its resistance to corrosion caused by organic and inorganic acids at elevated temperatures and high concentrations.

On the other hand, the alloys 5 and 6 show characteristics, similar to cast iron, and cannot be employed when the load consists of dynamical or impact stresses. Moreover these alloys do not behave well in welding, they develop stress-cracks. These disadvantages are partly overcome by adding some 4% Ni to the alloys.

Alloys 7 and 8 are suited for castings of large dimensions and their strength can be regulated by the heat treatment. Regarding the chemical properties, these alloys appear less advantage to replace the first group than alloys 5 and 6; however, in applications where the chemicals are neutral, or only weak acids or alkaline, they can be used. The properties of the two alloys 7 and 8 are not quite identical. While alloy 7 shows better corrosion resistance, alloy 8 makes a better material for ship propellers owing to its resistance to cavitational pitting.

**TABLE I.**

| No. | Type | Composition C % | Cr % | Ni % | Mo % | % | Strength Properties Yield kg/mm² | Tenacity kg/mm² | Elong. % | Brinell hardness | Weldeability |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Cr-Ni Cast Steel | 0.1 | 18 | 8 | — | — | 20 | 45-64 | 35 | 150-200 | not without heat treatment |
| 2 | Cr-Ni Cast Steel | 0.1 | 18 | 8 | — | Ti Ta+Nb | 20 | 45-65 | 25 | 150-200 | not without heat treatment |
| 3 | Cr-Ni-Mo Cast Steel | 0.1 | 18 | 8 | 2.2 | — | 20 | 45-65 | 35 | 150-200 | not without heat treatment |
| 4 | Cr-Ni-Mo Cast Steel | 0.1 | 18 | 8 | 2.2 | Ti Ta+Nb | 20 | 45-65 | 25 | 150-200 | Good |
| 5 | Chrom. Cast Steel | 1.0 | 28 | — | — | — | — | 45 | — | 250-300 | Not possible |
| 6 | Cr-Mo Cast Steel | 1.0 | 28 | — | 2 | — | — | 45 | — | 250-300 | |
| 7 | Chrom. Cast Steel | 0.2 | 14 | — | — | — | 45 | 65-80 | 14 | 240 | |
| 8 | Chrom. Cast Steel | 0.2 | 17.5 | 1.8 | — | — | 60 | 80-95 | 10 | 270 | |

period starting from 1930 in respect of corrosion and acid resistant alloy castings. These can be classified in three groups :

1. The austenitic steel alloys with 18% Cr, and 8% Ni, in addition some Mo and Cu might be added for singular purposes.

2. The ferritic-carbide alloys with 1-2% C and about 28% Cr. For improved corrosion resistance a small amount of Mo is sometimes added.

3. The martensitic steel alloys with 12-20% Cr and 0.2% C.

The composition and strength figures for these alloys are given in the following table.

The necessity of saving Nickel resulted in shifting the emphasis to the second group from the

The heat resistant alloys can be subdivided into 2 groups, the Cr-Ni-iron alloys and the Cr-iron alloys. The first of these have an austenitic structure, and consequently, the properties of austenitic steel. Their toughness is characteristic at room temperature as well as at elevated temperatures and, therefore, they are not sensitive to temperature variations, sudden heating and cooling. All Cr-Ni-iron alloys can be readily welded,

and their de-oxidizing properties, varying with the Cr content, are favourable up to about 1200° C. The only disadvantage they possess is their sensitivity to sulphur absorption, which is especially noticeable when treated in ovens. The general properties of these alloys are shown in the following table.

**TABLE II.**

| No. | Cr % | Ni % | Resist. to Oxidation in air | Yield kg/mm² | Tenacity at room temp. kg/mm² | Elong. % | Endurance Load kg/mm² | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | 600° | 800° | 1000° |
| 1 | 21 | 10 | up to 950° | 30 | 60-75 | 45 | 10.0 | 2.6 | 0.40 |
| 2 | 20 | 15 | up to 1050° | 30 | 60-75 | 45 | 8.0 | 2.0 | 0.50 |
| 3 | 28 | 11 | 900-1200° | 45 | 65-80 | 25 | — | 0.60 | 0.10 |
| 4 | 25 | 20 | up to 1200° | 27 | 60-75 | 40 | — | 2.0 | 0.40 |

Saving in Nickel with these alloys is possible only to a very limited measure, as by reducing the Nickel content, the austenitic character is changed, although the resistance to oxidation is almost unaffected.

The Cr-iron alloys have a ferritic-carbide structure with corresponding properties. As Table III. shows, at room temperature, the properties are similar to those of the Cr-Ni-iron group, with the exception of the elongation figure, which is much smaller with the Chrom group. Of greater significance are the properties at elevated temperatures, under the heading "endurance loading"; by this is understood that loading which produces 1% elongation during 1000 hours loading at the respective temperature. As can be seen these figures, too, are smaller for the Chrome group than for the Chrome-Nickel group. On the other hand the sensitivity to sulphur is less in this case.

intermediate casting temperature is selected high enough to ensure proper flowing of the metal in the moulds, yet not too high, to keep the structure as fine as possible. Several attempts were made to obtain finer structure by adding various alloying elements as Ti, Va, $N_2$, K, etc., but the results were not quite satisfactory. The viscosity could be improved by adding some Si, but the slightest excess of this would cause volumetric changes at higher temperatures, owing to transformation.

**Cast Steel Alloys with Specific Physical Properties.** For the electrical industry 12% Mn steel offers a good non-magnetic material and are generally replacing Ni-Mn steels, used formerly. For permanent magnets, 27% Ni, 14% Al steel castings are used with good results. This material is so exceptionally brittle that it can be only shaped by grinding the casting. Further improvement were noted by adding some Cobalt, up to about 25%.

The casting technique of permanent magnets is similar to that of grey and mottled cast iron. Small blow-holes in the material do not appreciably affect the magnetic properties.

In general it will be seen that with high-alloy cast steels the search for substitute materials did not bring about the same results as in case of the low-alloys. Small alteration of the alloying elements causes many considerable changes of the properties of the alloy. Nevertheless, in many instances, successful means were found to contribute to the much needed economy of raw materials in Germany.

**TABLE III.**

| No. | Cr % | Resist. to Oxidation in air | Yield kg/mm² | Tenacity at room temp. kg/mm² | Elong. % | Endurance Load kg/mm² | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | 600° | 800° | 1000° |
| 1 | 12 | up to 900° | 40 | 60-75 | 18 | 2.0 | 0.06 | — |
| 2 | 18 | up to 1050° | 35 | 55-70 | 15 | 2.5 | 0.30 | 0.05 |
| 3 | 28 | 900-1200° | 40 | 55-70 | 12 | 2.5 | 0.30 | 0.06 |

The tendency of heat resistant alloys to form a coarse granular structure, is responsible for some difficulties experienced already during the casting process. For accurate production of the casting a high temperature would be needed, but as this increases the coarseness of the structure, some

# FASTER PRODUCTION:

## DESIGN AND MATERIAL SELECTION. INSPECTION AND TESTING

*The following* 14 *Articles on Design and Material Selection, and* 8 *Articles on Inspection and Testing, conclude the series of articles on Faster Production abstracted from the American periodical, "Metals and Alloys." The first parts of the series have been published in the previous two issues of* THE ENGINEERS' DIGEST.

### CARBON STEELS AND DEFENCE CONDITIONS

By H. W. GILLETT.

SCARCE alloying elements should be reserved for those steels in which each alloying element plays an unique and non-substitutable role.

The real needs of the part in its final form, the use of any alloy steel for parts to be quenched and tempered in sections so small that they will harden through, should be scrutinized with care. And for carburized parts, the use of alloy steels in order to get a tough core—when tested *without* the case—is often quite unwarranted, since the piece seldom requires toughness anyway, and the carburized *part*, as a part, isn't tough, despite the core, because a crack in the case will propagate through the core despite its alleged toughness. In heavily carburized parts the case is made thick, not because we expect to use all that thickness to provide material to be worn away in service, but merely to give support to the surface, the working face. If the hard surface is backed up by a strong, relatively hard core, a thin case, quickly produced by gas carburizing, cyaniding, etc., or almost instantaneously produced by flame or induction hardening, may do quite as well.

For suitable backing, the depth of hardening obtained in medium, forging grade, plain carbon steel is often quite adequate. It is clumsy to use low carbon alloy steels and spend a long time carburizing them when an easily obtainable carbon steel can be processed in a jiffy to give something usually quite as good.

### ROLE OF PLASTICS

By J. DELMONTE, *Technical Director, Plastics Industries Technical Institute, Los Angeles, Cal.*

IT is not surprising to observe that in the new industrial activity plastics are playing prominent roles. Well adapted to mass production methods, moulded plastics are bringing their qualities of low manufacturing costs, lightness in weight, resistance to chemicals, heat and electrical insulating properties, and desirable mechanical characteristics, to many industrial parts.

While shortages of certain metals have contributed in part to increased activity in the field of plastics, the plastics industry abhors the use of the term "substitutes," because it feels that there are many applications which ultimately would have reverted to plastics. Notwithstanding, a large measure of the present consumption in plastics is occasioned by two basic motives: (1) their use will permit the release of strategic materials for defence purposes, where only the metal will suffice; or (2) rate, volume, or quality of production may be singularly fulfilled by plastics.

While the physical and chemical properties of plastics are of such character as to prohibit promiscuous use in every application which arises, reasonable care in analysis of design and study of operating conditions will soon reveal the proper type of material to employ. For example, highly popular in the new industrial

activity are impact-resistant phenolics as well as ureas, polyvinyls, polyacrylics, polystyrene and cellulose derivatives.

From this brief discussion it should be apparent that plastics have characteristics which merit attention when speed-up of production is required. Certainly they are not panacea for all design problems, but when applied in proper manner they are of unquestionable value.

## FINISHES FOR METAL PRODUCTS

By H. S. RAWDON, *Chief, Div. of Metallurgy, National Bur. of Standards, Washington, D.C.*

As the name indicates, the "finishing" of a metal product is essentially the concluding operation in the process of fabricating the product. Commercial finishes differ widely in nature, and they range from simple mechanical surface treatments to the application of highly decorative and protective surface coatings. The metallurgist's interest in "finishing" usually relates to the means used to render the metal surface resistant to the deteriorating agencies of corrosion and erosion, although the decorative aspects can never be entirely ignored even under stringent conditions. It is the protective aspects of the finishing of steel products which will be considered in this brief discussion of the finishing of metals as modified by the present conditions.

The defence-program restrictions on the ordinary civilian uses of zinc, tin, and nickel, the most widely used metals for coatings, have forced consideration of other metals for this use as well as of more economical coating methods.

Of all the metals now available in quantities, lead is outstanding. The use of lead for this purpose is receiving wide commercial consideration, despite the fact that a small alloying addition, usually of tin or other strategic metal, is necessary in order to ensure proper bonding of the coating to the steel base. Already lead has been adopted by some large manufacturers as replacement of zinc for various steel products ranging from woven-wire stucco reinforcement to miscellaneous pole-line hardware. The metal possesses many properties which distinctly favour its use as a coating for steel. The multitudinous rust specks that "pepper" the lead surface soon after exposure to the atmosphere are more usually undesirable from the standpoint of an unattractive surface appearance than because of deterioration by deep seated corrosion of the steel beneath. As a base for painting, lead coatings are unexcelled, as evidenced by the excellent performance of terne plate as a roofing material.

Economy in the use of zinc as a coating is a factor of increasing importance. Electroplating is outstanding in the metal coating industry as a means for making a small amount of metal "go a long way," and the increasing use of this method for the zinc coating of semi-finished steel products, sheet, strip, and wire, is very encouraging. However, the hot-dip coating industry has not acknowledged a "knock-out" in this field, but has accepted the challenge, and recent developments plainly indicate the feasibility of producing coatings by hot dipping which can compete with those of the other type.

It is by no means necessary, nor desirable, always to use a metal coating as a finish for the protection of steel. Conversion of the surface metal into a compound by suitable chemical treatment so as to increase the resistance of the surface layer is a method employed in a number of ways. Outstanding among these is the phosphatizing treatment. Although the surface film of ferrous phosphate, in itself, is limited as to the degree of protection it can give to steel, in combination with a paint, or lacquer coating, it is widely used with eminently satisfactory results.

A method of this general nature, recently proposed as a possible replacement of the tin-lead coating on the inner surface of soda-acid portable fire extinguishers, consists in the phosphate treatment followed by impregnation by means of a dilute solution of asphalt varnish in a volatile solvent. Such a coating shows much promise for use on other containers, such as garbage pails. In addition to furnishing a hard protective surface layer, it serves in the same manner as a galvanized layer does, i.e., to seal all crevices and make the container watertight.

Among other finishes which should find increasing application are lacquers. The use of pretreated stock out of which the product can be formed has already proved commercially feasible. A more extended use of this method is greatly to be desired.

## POWDER METALLURGY

By FRED. P. PETERS, *Associate Editor.*

THE moulding of parts to finished dimensions by pressing powdered metals in dies and then sintering, has only recently risen to prominence as another (and often faster or better) way of making certain parts ordinarily fabricated by casting and machining, by die forging, by stamping, etc. It is obvious that moulding to finished dimensions saves subsequent machining time, and thus also releases valuable machine tools for other work. Also, powder metallurgy presses are available that can produce small parts at rates up to 500 per min., although production rates are normally between 25 and 150 per min.

But the fact that this is being done with certain parts should not lead to the conclusion that powder metallurgy fabrication is the final answer to the faster production of small parts in general. The design of the part must be such as to accommodate this somewhat inflexible process, its operating conditions must be satisfied by the relatively low mechanical properties of many powder-compacts, and material cost factors must be considered. Similarly the number of parts to be produced in the same design must be large, since dies and tools are expensive.

From a design point of view, the powder method will not be available if the design includes re-entrant angles, undercuts or cross holes. True, the re-entrant angles or cross holes may be subsequently machined out, or split dies may be used, but economy or speed of production are considerably reduced thereby.

Material factors and engineering properties, too, are extremely important in considering the use of powder metallurgy for faster production. Seeling and Gordon have indicated that iron parts can be made by powder metallurgy at present with strength properties about the same as ordinary (25,000 lb.) cast iron or low-carbon steel. Brass and bronze parts, however, can be made by powder metallurgy with better physical properties than the cast materials.

Powder metallurgy is, perhaps, the fastest-growing of the high-production fabricating operations. As a means of saving machining time and making machine tools available for other uses, it merits the most careful consideration of every metallurgical design engineer entrusted with the responsibility of getting large-lot small parts made economically in the quickest-possible time.

## GRAY IRON IN PRODUCT DESIGN

By OLIVER SMALLEY, *President, Meehanite Metal Corp., Pittsburgh.*

IN the following the qualities of cast iron are examined in the light of what can be or is being done in respect to contribute to faster production.

(1) Production time: Modern foundry technique and organization have advanced a great deal by means of the application of modern production methods and machinery, with the result that iron castings in quantity can be manufactured comparatively rapidly.

(2) Accuracy in casting to shape: Improved foundry practice to-day permits the regular day-by-day output of castings in volume which will conform regularly to size and dimension specifications as well as to the engineering properties demanded.

(3) Flexibility for design changes, permitting lighter sections: Cast iron with its greater fluidity at ordinary pouring temperatures permits the casting of complicated shapes having wide variations of section accompanied by adequate strength without excess weight.

(4) Machinability: The easy machining properties of cast iron as opposed to steel are well known, and the chief problem in this connection has generally been the manufacturer's inability to secure castings uniform in properties and structure, and at least relatively free from defects. Recent metallurgical developments, however, have overruled this problem in many cases.

(5) Dependable engineering properties often without heat treatment: Achievement of superior engineering properties of cast iron without the necessity of long and expensive heat treatment is a fairly recent and exceedingly important development. Castings are available to-day with "as cast" tensile strength in excess of 55,000 lbs. per sq. in., and with a true modulus of elasticity of 23,000,000 lbs. per sq. in. Foundry technique also includes a control of hardnesses and, in fact, all the important properties that may be required for a casting's specific service conditions. Outstanding examples of speed in production are provided in munition manufacture where the wear-resisting and self-lubricating properties of cast iron shell-nosing dies, shell draw rings, and a wide variety of stamping dies are utilized.

## STEEL CASTINGS

By C. W. BRIGGS, *Technical Adviser, Steel Founders' Soc. of America, Cleveland.*

THE following suggestions are offered to buyers of steel castings.

Design: The characteristics of steel casting design are extremely important as to the speed with which the production of a casting is carried on. It is suggested that on all new designs the buyer consult the foundry operating executive before the casting design leaves the drawing board.

Foundrymen are able to give helpful pointers on design so that the work better fits their moulding equipment. They also can give the buyer suggestions on the joining of sections, the location of cores and many other items that will result in direct saving of time and cost of production of the casting. There are a number of fundamental rules in the designing of steel castings, which, if adhered to, will materially increase production as defective castings are less liable to be encountered. Such rules are for instance:

An attempt should be made to design all sections in a casting with uniform thickness.

It is not desirable to design cast steel structures with abrupt changes in sections.

Sharp corners at adjoining sections are sources of defects and, if possible, should be eliminated, etc.

Patterns: Casting purchasers should study the foundry's pattern requirements carefully. They should consult with the foundry so that they may be able to select the pattern equipment that will give them the desired pattern life at the most economical figure that will allow for the greater speed of production.

Models: Considerable time may be saved on pattern construction of intricate castings if models are built to scale. The model will assist the designer in making the prospective casting more castable. Patterns can be constructed faster and at less cost than it takes to make both pattern and model. It can save considerable time in bringing about necessary changes of design and in checking mould tolerances.

Tests: It is suggested that unnecessary tests be eliminated.

Composition: Production can be increased by using steels consistent with the needs. Do not request an alloy steel if a carbon steel will do equally as well.

## MACHINABILITY OF CAST IRON

By C. H. LORIG, *Batelle Memorial Institute, Columbus, Ohio.*

MACHINABILITY can only be defined in terms of practice. It depends on many separate factors which include such things as: The composition, structure, physical properties of the iron, the surface of the casting, the type of machining operation, the type of cutting tool used. Since the influence of these factors is mutually related, a reference to machinability of gray cast iron must take into account the effects of all of them.

Both the composition and structure of cast iron have a pronounced effect on the machinability. From the point of view of composition, high carbon and high silicon contents tend to improve machinability at the expense of mechanical properties. From the point of view of structure a totally ferritic matrix makes for easy machining. As the matrix becomes more pearlitic, i.e., contains more combined carbon, and as the amount of graphite becomes smaller, cast iron becomes more difficult to machine. Improved machinability with some sacrifice to strength and hardness may be obtained by an anneal at temperatures from 1400 to 1500 deg. F. This heat treatment increases the graphite and reduces the combined carbon content of cast irons.

A precise relationship between machinability and physical properties, applicable to cast irons in general, does not exist. The lack of some simple index of machinability among the physical properties is unfortunate, but is traceable to known differences that may be found in the behaviour and structural make-up of hardness or strength. The final test on machinability of cast iron is in the machine shop.

## WELDING DESIGN.

By A. F. DAVIS, *Vice-President, The Lincoln Electric Co., Cleveland.*

APPLIED by the engineer and designer, welding imparts greater structural strength, speeds production and cuts weight and cost. It increases strength over cast iron construction because rolled steel is four times as strong and two and a half times as stiff as ordinary gray iron, and over

riveted construction because the welded joint develops the full strength of the metal, whereas the joint riveted has to be weakened by drilling of holes.

Welding speeds production because it eliminates many operations required with other methods, such as the drawing and making of patterns and the excessive machining in cast construction, and the detailing, punching and excessive handling of extra connecting members in riveted construction.

Welding reduces weight over cast iron construction by virtue of the greater strength and rigidity of steel, requiring less metal for equal strength; over riveted steel construction by elimination of intermediate connecting members.

Reduced cost, with welding, is the logical result of the elimination of extra operations and saving of metal.

## COLD-DRAWN STEELS

By F. J. ROBBINS, *Metallurgical Engineer, Bliss & Laughlin, Inc., Harvey.*

ESSENTIALLY, there are 4 primary reasons for the widespread use of cold-drawn bars: (1) Close size tolerance; (2) good finish; (3) high strength; and (4) excellent machining. All of these are dependent upon the fact that the steel bars are drawn through a die made to very accurate size of good tool steel or of tungsten carbide.

The result of high accuracy is immediately apparent to those interested in the fabrication of parts of machine tools. Collet life is much longer, because their action is more uniform and positive. Cutting edges of tools are preserved over a far longer period because a uniform amount of metal is removed by each one, and the first-operation tools are not required to compensate for large irregularities in bar size. Thus, machine upkeep and tool cost are maintained at a minimum.

Removal of rolling scale by pickling, the compression in passing through the die, and careful supervision of the application of lubricant and the actual drawing process, result in a scale-free, smooth bar surface. After drawing, the bars are mechanically polished on specially designed equipment. The result is a smooth, shiny finish, which does very often suffice for the finish requirements of the part being fabricated.

In using cold-drawn bars, therefore, it is necessary to remove only the minimum required for shaping the part, and the cold-drawn bar surface is used to the greatest possible extent. This surface can also be used for some types of bearings run directly on it and for part surfaces to be subsequently coated in some manner, except, of course, where very fine polished surfaces are required. The economic advantage of this is readily apparent.

Frequently a sub-critical temperature anneal is employed further to increase hardness, tensile and yield strengths above the values as cold drawn. Further, such strain tempering results in restoration of the proportional limit to a high value as well as an increase in ductility.

In steels of medium carbon content when heavily cold-worked and subsequently tempered this factor is very important because no warpage or distortion are minimized and it is not necessary to heat treat parts made from steels produced in this way. The cold working performed upon all cold-drawn steels makes them stronger and harder than bars that have not been cold worked. The physical properties of such steel bars are suitable for thousands of parts that are used without any subsequent heat treatment. Improved part finish is a factor in such uses too, since wear resistance is to a great extent dependent upon a smooth surface free from torn and ragged tool marks.

To all industry, probably the most important effect of cold drawing is the increase in machinability and tool life, and the improved part finish resulting from its use. Primarily this, too, results from cold working. Increase in tensile, yield and hardness and the decrease in ductility (i.e., elongation and reduction of area) eliminate gumminess or mushiness in the softer areas. This allows the tool to pass through those areas more readily and avoids the development of high frictional heat.

## SILVER BRAZING ALLOYS.

By ROBERT H. LEACH, *Vice-President, Handy & Harman, Bridgeport, Conn.*

THE rapid increase in the use of silver brazing alloys for the manufacture of a wide range of products has been an outstanding development during the past few years. Commonly called silver solders for many years, these alloys have had a limited use for centuries, but the modern

methods of producing many kinds of equipment have created a large number of industrial uses for silver brazing alloys.

The melting point of standard silver brazing alloys runs from 1325 to 1600 deg. F., depending upon the composition. Two proprietary alloys, "Easy-Flo" and "Sil-Fos," have the advantage of still lower melting points and at the same time produce strong, shock-proof and corrosion resistant joints. Their free flowing properties at temperatures several hundred degrees below those required for the use of copper welding rods and base metal brazing alloys, make it possible to flow these alloys into closely fitted joints quickly with minimum chance of damage to the members that are being jointed.

The use of a closely fitted joint gives greater strength and results in economy because such a small amount of the alloy is necessary. Further economies in the use of these alloys are as follows: Saving in time and cost of labour; lower heating costs and lower finishing costs because of neatness of joint. These alloys are malleable and ductile and can be supplied in the most convenient form of sheet, strip or wire. They are adapted to practically any method of heating.

## BRONZE-WELDING IN REPAIR.

By W. S. WALKER, *Manager of Process Service, Eastern Div., The Linde Air Products, Co.*

FOREMOST among repair tests that bronze-welding is called upon to perform is the salvage of castings that, through hard service or by reason of accidents, have been cracked or broken. Castings that form a vital part of plant equipment, such as furnace sections, machine bases, pump and boiler sections, bearings, cylinders, etc., can often be restored in no other manner.

Bronze welding is particularly well adapted for welding cast iron. As it does not require melting of the base metal, the considerations necessary to insure the proper gray iron structure in a fusion weld are completely eliminated. Because of the lower temperature required, preheating is greatly simplified, preheating of the entire casting seldom being required.

Bronze weld metal with its tensile strength of about 60,000 lbs. per sq. in. and ductility in excess of 30%, greatly exceeds the tensile strength and ductility of cast iron. The rod metal bonds well with the cast iron; the bond, in fact, if properly made, being strong enough to pull cast iron away with it if a joint is tested to destruction.

Just about as inevitable a problem as breakage in an industrial plant is the problem of countering wear in moving parts or surfaces that come in contact with moving parts. Tailor-made for this work is a development of bronze-welding known as "bronze-surfacing," which employs the same basic technique and rod as bronze-welding, but differs from it in that it is employed not in joining broken parts but only as a means of adding metal to worn surfaces. This "building-up" process by bronze-surfacing has countless uses for plant maintenance. The free-flowing qualities of bronze rod makes it possible to apply it as a thin coating or to use it in building-up comparatively thick sections of homogenous metal. Bronze weld metal is readily machinable, which means it can easily be machined to the desired dimensions after application.

## SCREW MACHINE PRODUCTS

By D. H. MONTGOMERY, *Vice-President, New Britain-Gridley Machine Div., New Britain, Conn.*

THAT screw machines are capable of speeding the production of numerous metal products is so well understood that the makers of such machines are booked to capacity for many months ahead. In this article some suggestions are given, which, if followed, tend to simplify screw machine product manufacture. These rules are obvious to those who know screw machine work, but they are constantly overlooked, with the result that work which might be speeded is often unnecessarily delayed. If those who design and purchase screw machine products will check them against this list, much time and cost will be saved:

(1) Specify material which machines most freely and still meets other requirements. If possible name one or more other materials or optional analyses which can be substituted if that preferred is not quickly available.

(2) Design for a standard size of stock and the minimum size feasible so that minimum depth of cut and minimum scrap will result.

(3) If the piece must have a central hole, consider the possible use of tubing of standard size to avoid drilling either large or deep holes, with consequent scrap waste and slower machining.

(4) Design for minimum difference between head or flange diameter and body diameter.

(5) Avoid designs which require special tools not easily made available.

(6) Allow the widest dimensional tolerances feasible and never make them closer than required on mating parts.

(7) Never specify No. 3 thread fits when No. 2 or coarser fits will meet requirements.

(8) Design so that the number of operations required are minimized, and so that as many as feasible can be completed in the screw machine or in some stock attachment readily available, unless, of course, more rapid production can be assured by transfer to a secondary machine known to be available.

(9) Flange and other side faces, especially those to be cut by forming tools, preferably should not be required to make right angles with the axis, as this usually makes necessary extra operations or additional tools, or both.

(10) Do not specify finishes smoother than that left by the usual finishing tool, unless this be essential. Unless burrs must be removed, do not so require ; if required specify where.

## DIE CASTINGS

By Herbert Chase.

Die castings are ideal for certain and numerous defence applications primarily because the die casting method is among the fastest and most efficient of production processes. Yet we find the American die casting industry using only a small fraction of its capacity for turning out defence items.

The two basic reasons are: (1) That the metals chiefly used, zinc and aluminium, are not plentiful, aluminium, in particular, being required for aircraft needs. (2) That many of those in a position to make or dictate the use of die castings either fail to appreciate or to utilize them to best advantages or tend to lay undue stress on their limitations.

Both conditions doubtless will be corrected in due course. Many parts now produced on the screw machine, especially many made from brass, can be die cast in zinc alloy more rapidly and more economically and with no significant difference in performance.

Numerous brass and aluminium castings, especially many now made in sand moulds, as well as many iron sand castings could be converted to die castings in zinc alloy, also with great saving in time of production, and, in all cases, with reduced labour and decreased demands for machine work.

There are also cases in which die castings yield definite economics, especially in labour, over stampings and plastic mouldings, though space limitations prevent giving details here.

## DROP AND UPSET FORGINGS

By The Drop Forging Association, Cleveland.

Results of a brief survey among forging plants and users of forgings indicate that the adoption of certain specific practices could result in effecting further economies in the use of metal, substantially increase the rate of production and, in many cases, step up the rate of machining and finishing of forgings.

These practices are mentioned for the purpose of emphasizing their importance, and to stimulate a more intensive effort on the part of those who may obtain still further benefits from forgings. Some of the specific practices which might be thoughtfully considered and applied are:

Check over designs of parts to be forged for the purpose of discovering any parts which might offer a further reduction in dead weight if redesigned. Since it is possible with forgings to get plus strength in lighter sectional thicknesses, metal bulk is usually a needless waste of metal.

Often the loss of considerable time could be avoided, if designers and engineers would consult forging engineers about the problems of forging a specific part, to determine just what is possible and practical.

Check your specifications for steel from the standpoint of the physical values that you wish to obtain. Perhaps you can get the same physical values from another grade of steel by subjecting it to heat treatment after forging. If so, give your forging source specifications to cover the use of whatever grades of steel are suitable.

The elimination of excess finish and weight in the original forging, the adoption of precision hot punching and shearing practices, the coining of unmachined surfaces, the prevention of decarburization on surfaces subsequently hardened for wear resistance, the cutting down of wasteful flash and draft losses, are methods whereby the

production of forgings can be substantially increased, and machining and finishing operations greatly decreased.

Many small forgings could be made without scaling by changes in heating methods, thus eliminating pickling and cleaning. Induction heating with atmosphere control has been applied in some isolated instances. Atmosphere control of heating in large sizes of forgings to limit the scale and prevent decarburization would justify greatly reduced finish allowances, and, in many instances, avoid finish at all.

## NATIONAL DEFENCE MATERIALS.

By G. F. JENKS, *Colonel, Ordnance Dept., U.S. Army, Washington, D.C.*

IN the conversion of production in National Defence material, industries are being developed to tenfold and even hundredfold of their former capacities. Many units of these industries are manufacturing a product with which they have had no previous experience. These and other conditions have resulted in serious problems in recruiting and training inspectors. Both the recruitment and the training programmes are difficult, because so few have a knowledge of the conditions of use and requirements of military products.

The inspector needs to possess a knowledge of materials and processing methods and of the functioning and service requirements of the final product. The suitablity of a material for a given product depends, to a large degree, upon the process of fabrication. In many cases, the quality factor is fixed by the conditions and strains of processing rather than by the service use of the final product.

The conditions of use have likewise been used to express quality factors. Ordnance quality has long had a definite meaning in some of our steel plants. Aircraft quality is a newer term, but of more exacting requirements.

Intelligent decisions on the suitability of materials to meet the intent of the design engineer's specifications and to behave satisfactorily during subsequent processing operations, depend both upon a knowledge of the normal properties and structure of materials and of their defects and irregularities.

Long engineering experience in studying the behaviour of materials has given us a high degree of confidence in the behaviour of normal materials. We have had premature failures, and a science has been built up which correlates such failures with deficiencies both of design and of material. For a decision as to whether materials are abnormal, the inspector should know what defects and irregularities of structure are permissible for various products or classes of semi-fabricated parts. He needs to know the structure of the ingot for the various classes of steel and types of moulds, and how the irregularities and defects of structure are modified in subsequent operations. He needs, of course, the additional knowledge of the influence of those irregularities upon the behaviour of material when subjected to the strains of subsequent processing and to service loading and stress concentrations incidental thereto.

Ordinarily, an inspector obtains this knowledge of mill inspection practice through long experience and from the traditions of the mill handed down from prior generations. There is little literature on the subject. The absence of a literature makes the training of inspectors more difficult, and increases the probability of condemning materials which may be suitable.

## SPECIFICATIONS AND STANDARDIZATION

By FRANCIS J. JENKINS, *Chief, Procurement Section, 1st Lieut. Ordnance Dept., Watertown Arsenal, Mass.*

THE strong trend in recent years toward standardization, has benefitted not only the relations between industrial seller and buyer but has effected as well important savings in time, money and convenience, together with improvements in product quality and reliability.

The preparation of the material specifications that are the foundation stones of standardization can also be accomplished in each case with an eye to the elimination of all possible delay in "understanding" the material, in production, and in acceptance testing. Time and trouble will be saved by making the requirements of a specification definite and exact.

Consumer specifications should be formulated on the basis of the foundation laid down by technical society or governmental bureau specifications. By utilizing a standard specification,

the advantages of simplification are secured. By concentrating attention on one standard material of a kind, production is possible in larger quantities at lower cost, and better facilities are afforded for manufacturing, inspection and testing.

Tolerances should be wide enough to accommodate uncertainties of test methods. Special care must be also taken that the specification does nor " overspecify " by requiring material that is actually too good for the buyer's purpose. Also requirements should never be written around one particular brand of product. In general, reduction in tolerances increases costs, limits the number of supply-sources and extends the time required for testing.

A specification that follows a standardized form tends to eliminate confusion in its use, as familiar and oft-applied requirements are found where expected. Adherence to a definite sequence also may assure the inclusion of important details that would be otherwise overlooked by the specification writer.

The author has found the following practice quite satisfacory. The principal sections are grouped under suitable headings, which appear in capitals, are underscored and may be designated by arabic numerals, numbered continuously. Sub-sections within a single section are preceded by sub-headings, which are capitalized, underscored and set off by lower case letters in parenthesis. The requirements are generally grouped under the following section headings in the sequence indicated:

Scope
Applicable requirements
Manufacture
Chemical requirements
Physical requirements
Form and size
Size tolerances
Packing
Marking
Rejection

## MAGNETIC POWDER TESTING.

By A. V. DE FOREST, *Dept. of Mechanical Engineering, Massachusetts Institute of Technology, Cambridge, Mass.*

THE magnetic test for local defects developed by the Magnaflux Corp. has been in active use for only 10 years. Originating in a method primarily designed for finding surface cracks, particularly those due to fatigue, grinding and quenching, the most recent developments of the method lie in the very different field of locating non-metallic inclusions in raw materials as well as finished parts.

The nature and distribution of non-metallics has mostly been studied by micro examination of the small particles and macro inspection of the gross distribution after a deep etch. Both of these methods of examination are restricted to small areas.

The Magnaflux method of test has shown that, in numberless cases of incipient fatigue cracks, the cause lay in design of the part, the choice of the steel and its treatment, defective surfaces and corrosion, rather than in dirty steel. Recently the Magnaflux test has been applied to the problem of specifying aircraft quality steel. A test specimen of appropriate length and diameter is magnetized by a standard current passing through the part for a limited time and a standard concentration of indicating fluid is flowed over the specimen. Any longitudinal inhomogeneities are clearly shown and may be rated as to number, size, and distribution. A further magnetic inspection of each piece, after manufacture is complete, may be depended upon to eliminate any part in which a dangerous defect appears.

The decision as to rejectable limits for the raw steel will depend on the number of rejections of the finished parts and the cost of manufacture. Thus, for a maximum economy of steel, no arbitrary limits of acceptability need be set down if there is agreement as to the rejection limits in the finished part. The difficult question arises in reaching the latter decision. It is now far easier to locate non-metallics than to evaluate their effect on the mechanical strength of parts in service, but, fortunately, it is also becoming generally recognized that non-metallic inclusions act only as stress raisers and their effect is small as compared with insufficient fillets, corners of key ways, and oil holes. Also their danger depends on being near the surface where they are easily located, and on their direction in relation to the applied stress. Fortunately, again, in very many cases the stress direction follows the grain flow of the steel and hence the longitudinal axis of the inclusions.

The necessity for knowledge rather than prejudice in setting rejection limits is now better appreciated; and, due to the scarcity of steel, manufacturers of finished parts are more hesitant about unwarranted rejections. The wasteful rejection of past methods was primarily based on fear of unknown defects.

## METALLOGRAPHIC INSPECTION

By TRACY C. JARRETT, *Chief Metallurgist, Koppers Co., Amer, Hammered, Ring Piston Div., Baltimore, Md.*

IT is the author's purpose to present a brief outline to speed up the preparation of metallurgical specimens for macro and micro examination without decreasing the quality.

(1) Know what the specimen is to be inspected for.

(2) Supplier and user should reach an agreement as to what information the examination is to give.

(3) Select proper sample and thus eliminate resampling and extra specimen preparation.

(4) Use proper method for cutting-off specimen.

(5) Mount the properly-cut specimen in hard bakelite or prepared holders prior to polishing. This tends to prevent rounding the edges of the specimen and keeps the specimen flatter.

(6) Select proper polishing method.

A few hints that tend to help in the preparation of specimens are:

(1) Do as little work on a specimen as possible, but sufficient for the purpose at hand.

(2) Round the edges of the mounted specimen to be polished. This helps the flow of polishing solution between the surface being polished and the lap.

(3) Copper or nickel electro-plate small specimens whose edges must be accurately preserved.

(4) Do not use a large specimen when a small one will serve the purpose. Polishing a large specimen takes time.

(5) Do not permit any carry-over of abrasive material to succeeding operation. Absolute cleanliness at all times is essential.

(6) Group a number of specimens in the same mounting when conditions permit.

## WELDING-QUALITY STEEL

By S. L. HOYT and C. B. VOLDRICH, *Technical Adviser and Welding Engineer, Batelle Memorial Institute, Columbus, Ohio.*

LARGE tonnages of steel, with 0.25% C and under have been fabricated in the past decade or so by the new methods of welding. This is an excellent quality of steel for this purpose and, as compared to riveting, has affected the requirements placed on the steel mill in two ways. Scarfing and welding magnify the significance of impurities and defects, which riveting could ignore, which may necessitate much repair welding or even rejection of the plate. Welding has also increased the use of heavy plates, so the mill must combine good rolling quality in large ingots with the requirements of the designing engineer and the welder.

This swing to welding has fortunately occurred at a time when important improvements in steel making were being introduced—such as the scientific study of open-hearth operations, the installation of high speed rolling mills, vastly extended technological control of all operations, etc. Though specifications have been used in the purchase of the steel, and we are well aware of their place in industry, it has been the close cooperation between steel mill and fabricator that has given the welding industry its important raw materials of the necessary quality and at a price that promoted expansion.

The designing engineer has been quick to appreciate the greater possibilities of welded construction and is now calling for steels which come above the range of common carbon steel. Outside the costs the problem centres around securing the properties required by the engineer and the fabricator, and also getting the level of weldeability required for the welding conditions which have been laid out for the job. Commercial tolerances for the more important chemical elements are established, but the "natural" ranges for welded fabrication may differ from those set up by previous specification practice. The impurity elements offer additional problems.

Finally the engineer may set up additional requirements, especially if the steel is to be heat treated or must have some particular characteristic.

Without being able to consider all the points of this complex problem of specifying steel for welded fabrication, we have tried to indicate something of its nature. Obviously the individual case controls the requirements for weldeability, and no general rules can be written until the situation is more thoroughly analysed and much better understood.

## INSTRUMENTATION

By C. O. FAIRCHILD, *Director of Research, C. J. Tagliabue Mfg. Co., Brooklyn.*

WHILE it may be the case that a single specific and practical idea for applying or improving instrumentation can increase and improve production in some bottle-neck, it appears to this writer that more widespread improvement would derive from a set of facts and principles having general usefulness.

In submitting an itemised list of suggestions, in the hope that each reader might perchance find one item that has not hitherto come to his mind, one must realize that there are hundreds of men in speed-up plants, working day and night to keep up the pace, and finding their minds wracked, while they try to sleep, with tumbling ideas for speed—speed. We do not presume to offer any better ideas, but only to gamble on the chance that one was missed.

(1) The practice of any economy in instrumentation, that can slow up production, or lower the quality of the product, would seem to be questionable.

(2) Every industrial instrument now installed and in use should be put in tune with the times.

(3) Instrumentation, particularly in all of the metals industries, should be increased to the limit of the capacity of the instrument manufacturers, and in these industries, this means fully automatic control of all processes.

(4) Spare instrument should be available wherever a failure may mean a loss in production.

(5) Maintenance men should be available at the factory during all running hours.

(6) The full benefit of instrumentation requires that inspection departments be cleared of all delay, and inspectors placed at all strategic points in production departments, where they can warn of conditions causing rejections as soon as possible.

(7) Whenever new instruments are being ordered, standard designs should be specified, not special in any way even as to scale range, unless the special feature is as urgently required as any item assigned an A1-A priority.

## MASS RADIOGRAPHIC INSPECTION

By ROBERT C. WOODS, *Physicist, Bell Aircraft Corp., Buffalo, N.Y.*

BASED on the quantity of work now done by the average industrial X-ray laboratory, it appears safe to assume that the use of more than 500 sq. ft. of X-ray film per day constitutes mass radiographic inspection. When this figure is reached or surpassed, efficient operation demands considerable thought as to laboratory design, type of equipment, and general organization. Because the aircraft phase for the moment overshadows other national defence X-ray applications, the present discussion will be confined to this field, although many of the points are applicable on a wider scope.

Some general suggestions are as follows.

Pay more attention than customary to dark room layout and equipment. Radiographic output is limited by processing facilities, and an undersized developing tank, or insufficient hangers or a poor technician can bottleneck everything.

Allot more space than at first appears necessary to the exposure room and provide the best possible illumination. Whether the original intent is so or not, there will necessarily be some experimental work done if full economic benefit is to be derived from the X-ray laboratory.

Above all, provide X-ray equipment with the widest possible range of penetrations—for aircraft work, preferably from 25,000 volts to 220,000 volts. Where only one machine is available and considerable latitude of inspection is desired, the older type air-cooled open X-ray tube is undoubtedly superior to the modern completely enclosed, liquid-cooled tube. In the latter, a certain amount of X-ray filtration is inherent and can be increased, but not decreased. By modification of the older type, however, almost any filtration or voltage is available, from the energizing of a tube used for crystal diffraction studies up to the radiography of 2 in. of steel or more.

Good layout and equipment are useless for production radiography without a competent system to route aircraft parts through the laboratory. Reception of parts, arrangement, identification, X-ray exposure, film processing, film interpretation, sorting good from rejected pieces,

and report preparation are all activities which should proceed on a schedule.

Although any production system should work on a schedule, still there must be enough flexibility to allow for emergencies, such as rush jobs from machine shop and experimental departments as well as from the airplane assembly line itself.

## SPECTROGRAPHIC ANALYSIS

By CHARLES C. NITCHIE, *Industrial Sales Div., Bausch & Lomb Optical Co., Rochester, N.Y.*

THE success that has attended the use of spectrographic methods of analysis in the laboratories of metallurgical and manufacturing plants throughout the country is a clear indication that just such a development has been accomplished. Iron and steel, aluminium, copper nickel, magnesium lead and zinc—these and the many other metals and alloys, so essential to the program for National Defence are all being produced under spectrographic control.

Time is saved and production increased because analyses are made so rapidly and with such quantitative accuracy that frequent checks can be made to be sure that operations are proceeding properly and that the metal is of the required composition before it is poured in the moulds. Errors in the furnace charge or in processing are detected in time to permit correction.

The speed and extreme sensitiveness of spectrographic analysis are proving equally valuable to the manufacturer who uses the products of the smelter and refinery. Small variations in the composition of alloys, or the presence of traces of impurities often result in marked variation in the physical and other properties. With the spectrographic analysis inspection is carried out quickly and accurately, checking both the essential alloying elements and also any undesirable impurities that may be present. This is particularly important to those industries that use secondary metals which may contain impurities that are not ordinarily found in virgin metals of that same kind and that might, therefore, escape detection if analysis were made only by conventional chemical procedures.

These are but a few outstanding examples of the way in which spectrographic analysis is helping to speed up the production of defence materials. Many others might be cited not only in the metal industries but also in other fields where close control of composition and purity is essential.

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## INFLUENCE OF DIMENSIONS AND TEMPERATURE ON IMPACT TEST FIGURES

By V. K. TSELIKOV. (From *Zavodskaja Laboratoria*, Moscow, No. 4, 1941, pp. 437-439).

THE following experiments were all carried out with steel from the same ingot, rolled into 20 × 80 mm. steel bars. A sample was taken at each end of each bar for chemical analysis and to check the macrostructure. Only bars showing carbon content within the limits of 0.2 to 0.25% and of like structure were retained for use in the tests. They were cut up into 300 mm. lengths, and once again tested for uniformity of macrostructure, then heated to a temperature of 1100° C., oven-cooled, and normalised at 860° C. with subsequent cooling in air. The microstructure after this heat treatment was as shown in Fig. 1.

In order to investigate the influence of span on impact test figures, specimens of a cross-section 8 × 8 mm. square were prepared in 50, 63, 70 and 90 mm. lengths for testing with spans of 35, 40, 45 and 50 mms. respectively. Accordingly, the angle of deformation on fracture was the same for all specimens, namely $2\alpha = 46° 50'$ the angle given by standard specimens of 10 × 10 × 55 mms., with Charpy type tests.

The notch, milled out with a special cutter, was 2 mm. wide by 1 mm. deep, with 1 mm. radius at the bottom. All dimensions were adhered to within fairly fine limits.

Experiments were carried out to determine the effect of changes of span on (a) the nature and extent of the plastic deformation with constant impact velocity; and (b) on the critical temperature for brittleness, with constant and variable impact velocity.

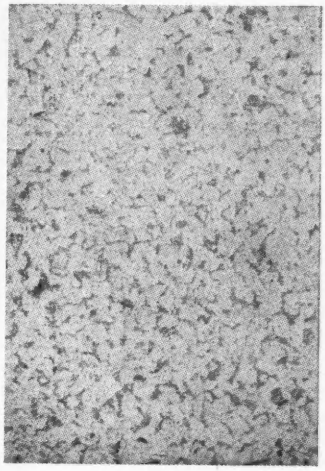

Fig. 1.
Typical mictostructure of impact test specimens.

In the case of (a) the sides of the specimen, i.e., the surfaces perpendicular to the notch, were polished. The tests were made at room temperature with a 15-kg. Amsler pendulum impact testing machine with an impact velocity of 6.5 metres/sec. and a blade width of 16 mm. The following conclusions were established:

(1) The zone of plastic deformation increases with span.

(2) With short spans the cross-section at fracture is more distorted than with long ones (see Fig. 2).

(3) The zone of crystalline fracture increases with span.

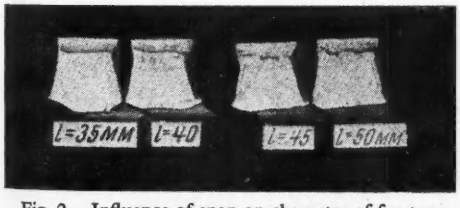


Fig. 2. Influence of span on character of fracture.

In order to permit of a more precise quantitative evaluation of the extent of the plastic deformation zone, ten specimens out of each batch were painted on the sides with shellac and tested when the shellac had set, but had not yet hardened to such an extent as to flake off on impact.

By this means the region of plastic deformation became quite sharply defined due to a multitude of small cracks in the shellac film which, incidentally, changed their direction appreciably with different spans: they ran at about 10 to 15° to the direction of the blow with 35 mm. span and at 20 to 25° with 50 mms. The same change in span resulted in the area showing signs of plastic deformation being increased by 18 to 20%, while the "energy to fracture" showed an increase which worked out to 2.1 kg-metres per sq. cm. of cross-sectional area.

Other specimens were tested with the same Amsler apparatus at low temperatures. Five tests were made with each of the four span lengths at temperatures varying by 10° C. They were cooled in batches of 20 in a thermostat, but no special precautions were taken to prevent heat absorption by the specimen while setting it up for test, as it was found that the temperature only rose by 2 to 3 degrees during this operation.

The results thus obtained are shown in Fig. 3, from which it will be seen that with changes of span from 35 to 50 mms. the critical temperature of brittleness rises by 18°.

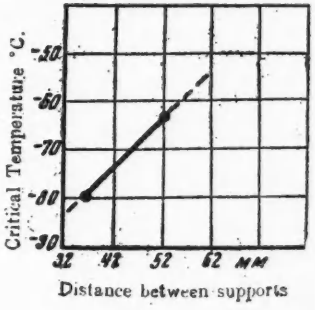


Fig. 3
Influnce of span on critical temperature of brittleness.

In order to investigate the influence of width of specimen on the extent of plastic deformation, specimens of 4, 8, 12 and 16 mms. width were made out of the same steel with a common height of 10 mm. The length of specimens and the test span were kept constant at 60 mms. and 45 mms. respectively, so that the angle of deformation was the same throughout. The notch was again the standard 2 mm. Mesnager type as previously described. Five specimens of each size were tested in the Amsler machine after painting with shellac, which showed up the zone of plastic deformation quite clearly. The results are shown in Fig. 4, from which it will be noted amongst other points that the curve of "specific volumetric toughness" (i.e., energy

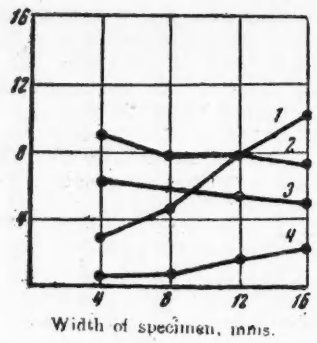


Fig. 4. Influence of specimen width on the energy absorbed at fracture in kg.-metres (1), on the energy per sq. cm. (2), on the energy per cub. cm. (3), and on the volume of plastic deformation (4).

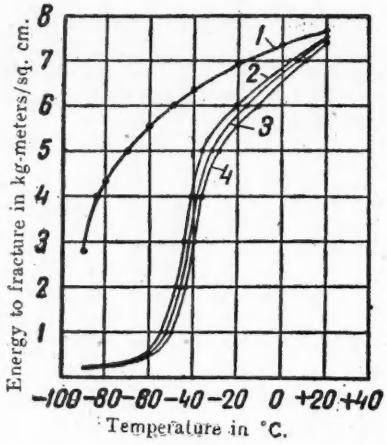


Fig. 5. Influence of the temperature on the energy absorbed at fracture with specimens of different width.

(1) Width of spec'n 4 mm. Spec'n section 4 × 8 mm.
(2) „ „ „ 8 „ „ 8 × 8
(3) „ „ „ 12 „ „ 12 × 8
(4) „ „ „ 16 „ „ 16 × 8

absorbed at fracture, per cu. cm.), curve No. 3, definitely falls as the width of specimen increases, which is contrary to the data put forward by Moser.

Variable width specimens were also used for low temperature experiments, the results of which appear in Fig. 5. It will be noted that, while the specimens of 8, 12, and 16 mm. width have almost identical temperature characteristics, reduction to 4 mms. has a very drastic effect on the "impact strength temperature" curve.

A further set of experiments was designed to study the influence of working height of specimens on the critical temperature, and for this purpose specimens of an identical size, but with varying depth of notch, were used. The dimensions were: width 10 mm., height 12 mm., length 60 mm., span 45 mm. Notches of 2, 3, 4, 5 and 6 mms. depth were cut, resulting in specimens of net sectional area of respectively, 100, 90, 80, 70 and 60 sq. mms.

The notches were again of the Mesnager type, milled under identical conditions, and again five specimens of each size were tested at each step of 10° C.

The results obtained are summarised in Fig. 6: the curves are closely bunched together for the deeper notches, but that for a notch only 2 mm. deep is distinctly apart from the others, showing a critical temperature some 20° C. lower and 0.5 kg-metres/cm² greater impact strength. This effect would appear to be due to the influence of energy absorbed by the surface layers on the notched side of the specimen.

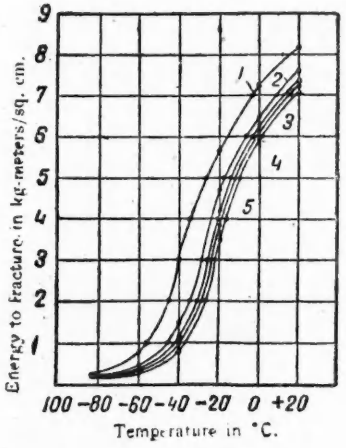


Fig. 6. Influence of temperature on the energy absorbed at fracture with specimens of different height.

(1) Working height of spec'n 10 mm. Sect. 10 × 10 mm.
(2) „ „ „ 9 „ 9 × 10
(3) „ „ „ 6 „ 6 × 10
(4) „ „ „ 8 „ 8 × 10
(5) „ „ „ 7 „ 7 × 10

# SYNTHETIC MATERIALS AND CLIMATE

By Dr. Ing. Hans Klingelhöffer. (From *Das Industrieblatt*, Vol. 46, No. 13, May 6th, 1941, pp. 635-637).

Recently much thought has been given to special technical problems arising from the climate in the Tropics and Colonies. In general, the effects of climate upon the human constitution were examined, but the problem includes also the suitable selection of materials, able to withstand the actual weather conditions. Under adverse climatic influences a small defect in the structure of a synthetic material may be more critical than under the conditions attaining in a conditioned workshop. Many examples could be quoted here, to illustrate the disastrous effect of giving insufficiently careful consideration to the actual working conditions.

The engineer working in the factory cannot be expected to be familiar with the prevailing temperature and humidities at far distant places, and, therefore, his guide are the specifications laid down in Germany by the VDI:

| | Flying Conditions | Temperate | Tropics Damp-hot | Tropics Dry-hot |
|---|---|---|---|---|
| Temperature | —60°C | 15..25°C. | +45°C. | +60°C |
| Humidity | (100%) | 65..80% | 90% | 15% |

It can be seen that the limits are extreme, and it is not an easy task to develop synthetic materials suitable over such a wide working range. The desired result might, however, be approached by employing high quality, pressed synthetics, provided their physical behaviour under varying temperature and humidity conditions is carefully examined.

Synthetics, like all other substances, have a three dimensional thermal expansion. With foils, or laminated synthetics, the expansion in one or another direction may show aberration, but this is rather the exception than the rule, and generally it is sufficient to examine the expansion in one direction only. Fig. 1 shows the thermal expansion curve of a particular class of synthetics and for comparison's sake, that of steel is also indicated.

Reinforced synthetics can naturally only be fully utilised if the expansion coefficient of both the metal and the synthetic is known. Such is the case also with press fitted articles, fabricated of synthetics. The minimum tolerance for thermal expansion must be adhered to if seizing is to be avoided. The development of plastics resistant to the atmosphere is, therefore, based on a full knowledge of their behaviour under various temperatures and humidity conditions.

While the temperature variation effect penetrates, so to speak spontaneously throughout the whole of the material and the consequent expansion appears as a volumetric change, humidity affects the outer surfaces first, and penetrates into the interior of the material very slowly, the rate of the dimensional change so caused being slow, continuing sometimes for several weeks.

Referring to Fig. 1, the portion (b) of the graph represents a contraction of the synthetic while heated in a furnace owing to the loss of water content; this part of the curve is a slow rate contraction, and was registered during a time interval of 14 hours. The portion (c) of the graph represents contraction during subsequent cooling. Comparing this result with that of the steel specimen, it becomes clear that in the case of synthetics the problem of expansion has become more complex by the introduction of an additional factor, namely the humidity. In practice the problem is even more complicated, as humidity does not affect the whole of the material simultaneously, the effect starting at the surface.

This effect can best be studied on samples exposed to water vapour along one side only.

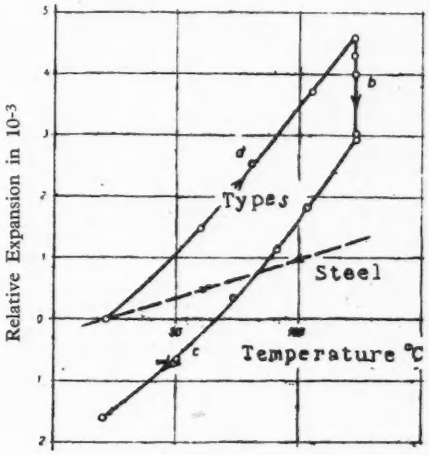


Fig. 1

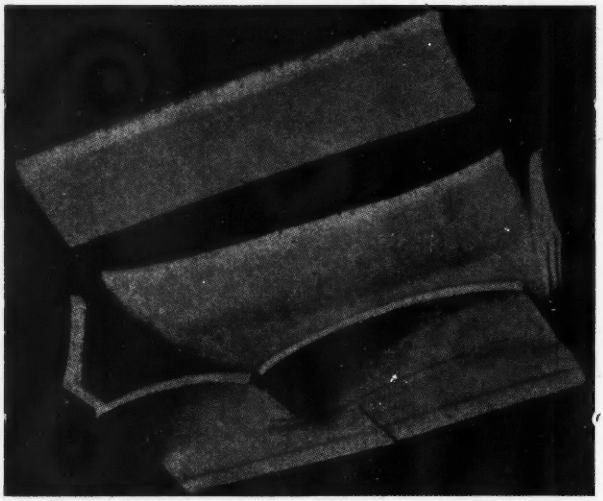

Fig. 2

Fig. 2 shows a thin walled box which was filled with hot water for some hours. The humidity inside the box results in rapid breakdown of the sample, a dangerous phenomenon even with high quality synthetics.

The above mentioned characteristics are the conclusions of a few very simple tests. There are means of overcoming these difficulties; as an example, by selecting a synthetic which would not absorb water. On the other hand it is not obvious that a combination of heat and humidity will produce the greatest stresses. Rubber, for instance, is far more affected by a dry-heat than by a damp atmosphere. The effect of very low temperatures upon the material in view of its water content has not been investigated as yet, though obviously this will considerably influence the mechanical properties of the synthetic; this again could not be generalised.

Although scientific research work contributes a great deal to the knowledge of materials, the most helpful method of determining whether a particular material is climate resistant or not, is by means of an artificial climate produced in the laboratory. Fig. 3 shows such an instrument in which the temperatures can be regulated between -15 and +70° C. and humidity between 20 and 95%. A rapid change of the "climate" is brought about by using small air furnaces, and the article is exposed to a blast of air of the required condition.

Apart from temperature and humidity, other climate factors, too, affect the material. As an example, the sunshine might cause discoloration and reduction of transparency of some materials (organic glass). These effects, too, can be examined in a properly equipped laboratory.

In view of the above the question is whether synthetics can be used at all under adverse weather conditions. The answer is in the affirmative. Good quality synthetics can be used under severe conditions; many applications will clearly show that the future of the synthetics is by no means limited to indoor applications, or even to exposure to milder conditions. But a thorough knowledge of the behaviour of the material under these conditions is indispensable.

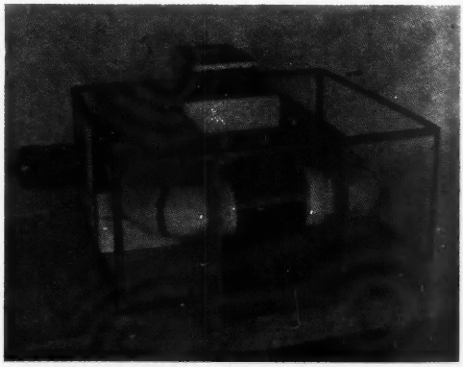

Fig. 3

## MILLION-VOLT INDUSTRIAL X-RAY UNIT

(From *Electrical Engineering*, Vol. 60, No. 11, November, 1941, p. 561/2 and No. 12, December, 1941, p. 571/3).

THE latest achievement of the General Electric Company's X-ray apparatus is a portable, completely sealed, 1500 pound self-contained 1000-kv unit shown at the right in Fig. 1. The effective radiation is the equivalent of that from about 100 grammes of radium, which would represent a cost of some $2,500,000 and enables industrial radiographs of heavy castings and heavy welded pressure vessels

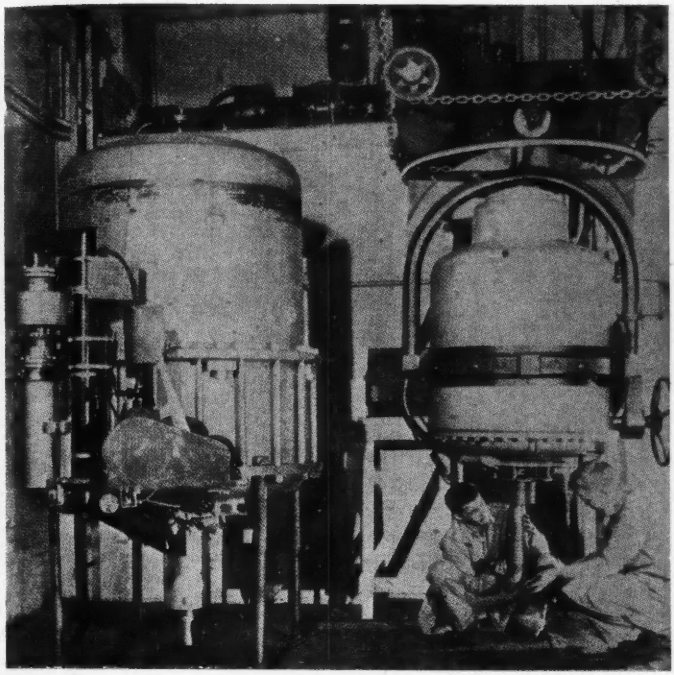

Fig. 1. At left: Two-ton laboratory model of 1000-kv X-ray unit; Intermediate step in the development of the
At right: New completely sealed, self-contained, 1500 pound portable 1000-kv X-ray unit.

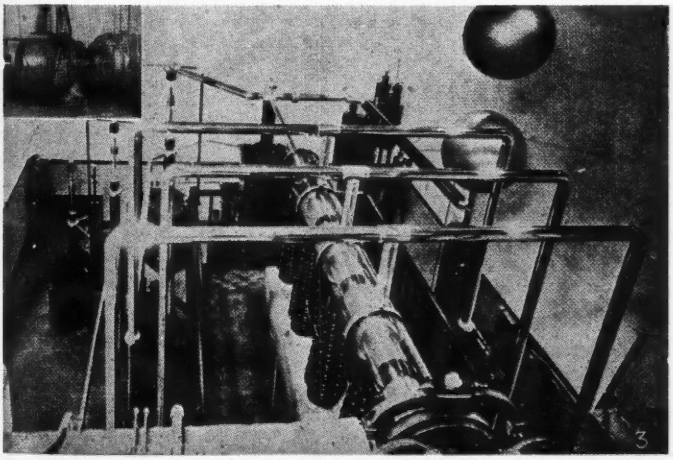

Fig. 2. 800-kv X-ray equipment as in use a few years ago. The insert shows the new portable 1000-kv unit to approximately the same scale in terms of the man shown at the left on the main figure. The extension chamber of the portable unit is just placed inside of a boiler drum.

to be made at a rate 64 times the best previously available (from 400 kv equipment). Also, for example, radiographs through five inches of solid steel can be made in two minutes instead of 3½ hours as before.

The two-ton laboratory model shown on the left of Fig. 1 represents a previous step of the development being an adaptation of a 1000-kv equipment designed for medical purposes. Only a very few years ago an 800-kv X-ray equipment required a special multistory housing (Fig. 2), and utilized a multisection X-ray tube about one foot in diameter and 14 feet long. The insert of the figure shows the new 1000-kv unit to approximate the same scale in terms of the man shown in the main figure. The over-all height of the new apparatus is 7 feet.

Three developments of co-ordinated research stand out as major factors of the new design: (a) dichlordifluormethane ("Freon") instead of air or oil as an electric insulating medium; (b) a compact air-core resonance transformer; (c) a multisection X-ray tube small enough to be accommodated within the core space of the transformer. Dichlordifluormethane has 2.5 times the insulating strength of air at equivalent pressures. At 50 pounds per square inch pressure its di-electric strength is three times as great as that of the purest transformer oil. In a very high-voltage unit, 100 pounds of this gas will give the insulation equivalent to that provided by 12,000 pounds of oil. Gaseous admixtures do not contaminate Freon the way water or other

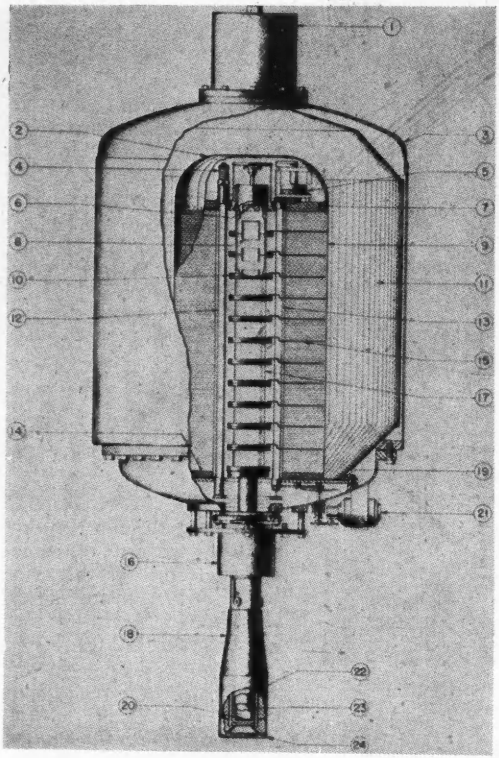

Fig. 3. Million-volt Portable X-ray Unit.

1. Cooler
2. Slotted brass shield
3. Steel tank
4. Spring for tie-rod
5. Variable reactor
6. Cathode assembly
7. End-turn filament coil
8. First intermediate electrode
9. Secondary coils
10. Shields around the X-ray tube
11. Laminated shield
12. Glass tie-rod
13. Insulating shaft for filament-control
14. Primary winding
15. Tap lead
16. Focusing coil
17. Glass envelope
18. Lead shield, adjustable
19. Laminated steel bottom
20. Tungsten target
21. Filament-control motor
22. Water jacket
23. Extension chamber
24. Lead diaphragms

foreign matter contaminate oil. The breakdown values of Freon are consistent, whereas oil is erratic.

Details of the design of the new unit are shown in Fig. 3. The cooling problem is solved by means of a small built-in cooler (1) utilizing a 1/15-horsepower fan to circulate the Freon-gas over water-cooled copper tubes and through the transformer.

In the resonance transformer the charging current of the high-voltage terminal is made to flow through a large inductance coil without iron core producing exactly the high-voltage wanted. The inductance of the coil and the capacity of the high-voltage terminal have been chosen to resonate at the frequency (180 cycles per second) of the power supplied to the transformer (4 kW to operate the equipment at 100 kv and 3 milliamperes). The high-voltage coil (9) is 30 inches high with 18-inch outside diameter and 8-inch inside or core-diameter. Some 238 miles of wire are accounted for in the transformer. The primary winding (14) is placed at the bottom, the high-voltage terminal on top of the transformer. Glass rods (12) hold the stack of the coil elements together, thereby allowing operation in any position.

The 12-section sealed-off X-ray tube (Fig. 4) is only 30 inches long, $3\frac{1}{2}$ inches in diameter and has cylindrical accelerating electrodes (8) in each

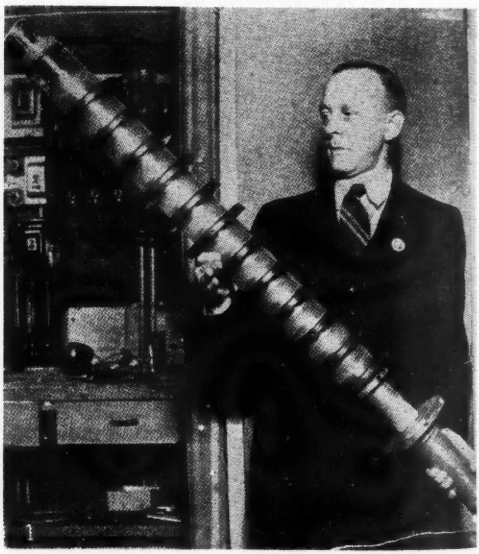

Fig. 4. X-ray tube of the new 1000-kv X-ray unit.

of the intermediate sections between the cathode and the copper-backed tungsten target. These intermediate electrodes are joined to the glass envelope of the X-ray tube with Fernico ring seals. Fernico is a special alloy which has an expansion co-efficient comparable with one of the borosilicate glasses, thus permitting heavy metal sections to be fused directly to the glass. The tube is supported entirely by a metal flange joined to the grounded extension chamber (23). This extension chamber houses the target end of the X-ray tube and thus permits the target to be placed inside of boiler drums and in other such relatively inaccessible positions.

Small toroidal shields (10) of a conducting Textolite are used around all Fernico seals to reduce the field strength at the Fernico edges, to aid the focusing action of the intermediate electrodes and to provide a contact point for the tap strips (15) which connect the intermediate electrodes to the inside of the transformer coil.

A focus coil (16) is provided outside the tank around the cooling jacket (22) of the extension chamber, to focus the electron beam on to the tungsten target (20). The focal-spot diameter may be chosen to correspond to the tube current, which can be adjusted from microamperes up to 3 milliamperes at a million volts. Power for the cathode filament (6) is derived from end-turns on the high-voltage winding and is controlled by means of a variable reactor (5) operated through a glass rod control shaft (13) by an external filament control motor (21).

Portable units like that described are in daily use at plants of Ford Motor, Babcock Wilcox, Combustion Engineering and General Electric Companies, and other units are being built for other industrial plants and for the United States Navy. The pressure of production for national defence has been a major factor in expediting the development and application of such equipment.

## THE 220,000 VOLT SYSTEM OF THE HYDRO-ELECTRIC POWER COMMISSION OF ONTARIO

By A. H. FRAMPTON and E. M. WOOD, H.E.P.C., of Ontario. (From *The Bulletin of the Hydroelectric Power Commission of Ontario*, Vol. XXVIII., No. 7, July, 1941, pp. 213/29).

(Paper presented to the American Institute of Electrical Engineers at Toronto, June, 19th, 1941).

THE rapid growth of this system, which belongs to the greatest transmission systems of the world, is illustrated by the following figures :

| | | |
|---|---|---|
| 1928 | First 220 kV line put in service .. .. | 240 miles |
| | Transmitted energy approximately .. .. | 110,000 kW |
| 1941 | In operation 220 kV lines approx. .. .. | 1,000 miles |
| | Receiving terminal station, Leaside, near Toronto .. .. | 420,000 kVA |
| | Second receiving station, Burlington, First installation .. .. | 150,000 kVA |
| | Ultimate installation | 450,000 kVA |
| | Total primary load inclus. 110 kV | |
| | Dec., 1929 .. .. .. | 710,000 kVA |
| | Dec., 1940 .. .. .. | 1,125,000 kVA |

The outbreak of the war brought the expectation of rapidly accelerated power demands. Therefore, the construction of a fourth circuit from the Beauharnois Heat and Power Comp. in the Quebec section of the St. Lawrence River was immediately undertaken (Fig. 1), and the new terminal station at Burlington, 45 miles west of Toronto, added. For the connection of Leaside and Burlington the first double circuit line for 220 kV of the system will be built. Diagram of the proposed development of Burlington is shown in Fig. 2. Three transformer banks will correspond to the existing phase of development.

**Summary of Operating Experience, 1928-41.**
(8400 circuit-miles-years).

Standard suspension tower used throughout the system during this period is shown in Fig. 3a.

| | |
|---|---|
| Total number of faults on lines during 13 years due to all kind of causes | 111 |
| Among those caused by various construction hazards | 4 |
| By miscellaneous causes (external) | 8 |
| Faults to be included in further study | 99 |
| From these faults attributed to lightning | 97 |

(a) Lightning. Majority of lightning faults (56) involved only one wire and ground, 25 involved two wires and 14 three wires and ground. Only one case involved two and one case three circuits. The remarkable grouping of 70 located faults in the Chats Falls-Leaside lines in relation

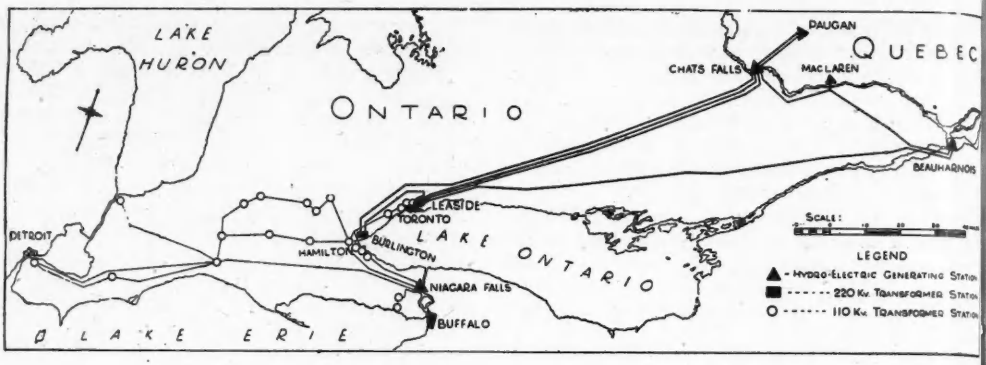


Fig. 1. The Niagara System of the Hydro-Electric Power of Ontario showing major generating and transformer stations and 220 kV and 110 kV lines.

to the tower footing resistance is shown in Fig. 4. It will be seen that 90% of the located outages occurred in the section of high footing resistances. An analysis of all records and all figures available had the following result :

| Average tower foot resistance | Outages per 100 circuit mile-years |
|---|---|
| Under 25 Ohms .. .. | 0.19 |
| 25 to 50 „ .. .. | 0.41 |
| 50 to 200 „ .. .. | 1.08 |
| over 200 „ .. .. | 5.1 |

Mean value for 8,400 circuit-miles years 1.15

The design of the towers of these lines shows a shielding angle of 42 degrees (Fig. 3a), and a ratio of " height of ground wire above power conductor to total height of ground wire " of 0.182. These values are considered as recommendable. (See Wagner, McCann and MacLane, A.I.E.E., Summer Convention, 1940).

(b) Mechanical-Sleet and wind. Though sleet storms frequently occur in the territory under consideration and the phenomenon of " galopping conductors " has been observed at not infrequent intervals, only two outages are attributed to sleet. They were caused by great differences of the sag of the power conductors and the ground wires in a very long span, which were produced by unbalanced loadings on the two sides of the adjacent suspension insulators. In two similar cases no outages occurred, as the conductors were not disturbed by wind.

(c) Vibration. In the original design of the lines under consideration the problem of vibration, brought to the attention of transmission engineers just in the period of the erection of these lines, was recognized by providing a reinforcement of a 6-foot length of the conductor fastened at its outer extremities and supported above the main conductor in a double seated suspension clamp (Fig. 5). In the second and third circuit standard armour rods were used. Although conductor fatigue due to vibration could be anticipated—maximum tension at ½" ice, 8 lbs. wind and 32 deg. Fahr., 35% of ultimate

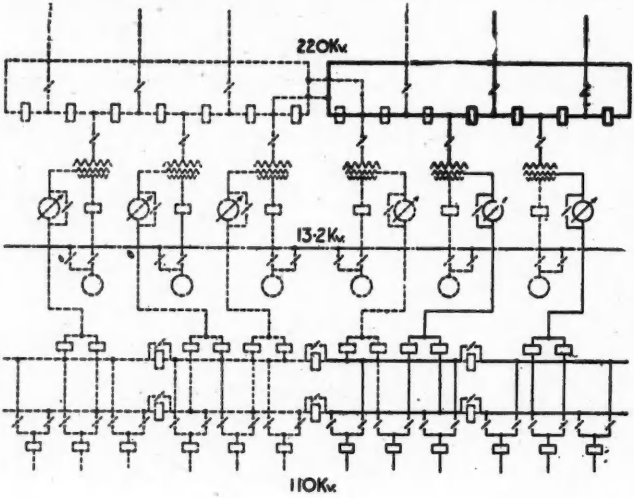


Fig. 2. Burlington 220 kV receiving terminal. Proposed ultimate diagram for six 220 kV circuits and six 75,000 kVA transformer banks. Initial installation (1941) in heavy lines.

Fig. 3: (a) Outline of original single-circuit 220 kV tower; (b) Corresponding outline of revised 1940 tower.

strength and 16% at 60 deg. Fahr.—no serious conditions have been observed up to now. It has been found necessary to provide lock nuts for all one and two bolts positions of the towers.

**Revisions Incorporated in the Design 1940/41, Single Circuit.**

(a) Lightning. Ground cables were raised eight feet above their original location in regard to sleet operation. This had the result of decreasing the shielding angle to 29 degrees and increasing the ratio "of height of ground wire above power conductors to total height of ground cables" to 0.263. In the earth sections of the new line footing resistances were found not exceeding 15 Ohms generally. In these sections no treatment beyond the occasional crawfoot is contemplated. In the rock section it was decided to lay a continuous counterpoise, consisting of 5/16 steel conductors. The performance of the new circuit will carefully compare to that of the existing circuits, as such performance will largely dictate whether counterpoise circuits should be added to the older construction.

(b) Mechanical-Sleet and wind. Thorough study was devoted to the question of the new tower design, based on Lissajous-figures and on all experience available. But substantial mileage of towers on stock influenced final decision. Fig. 6a shows the new tower. Movements of conductors in half loops has been assumed in providing spacings. Substantial clearance of ice loaded ground cable from unloaded conductors is shown in the figure.

(c) Vibration. The excess strength of the original tower design has been utilized to increase the ruling span from 1056 to 1150 feet. In order to maintain the same ground clearance a cable of

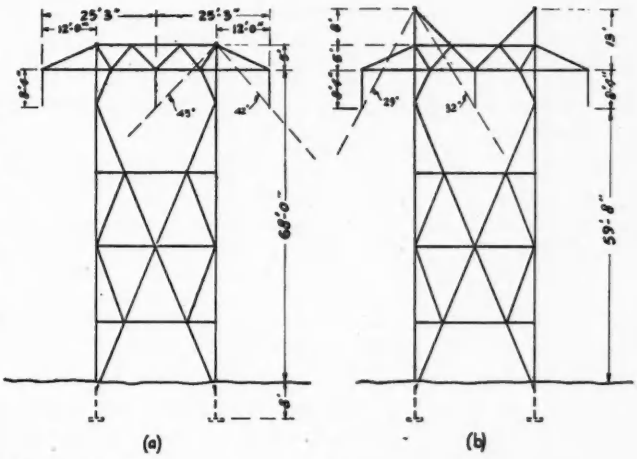


Fig. 4. Represents one lightning fault in the respective four mile section (5 towers per circuit mile). Tower footing resistance figures are average values for the 60 towers in each four mile section.

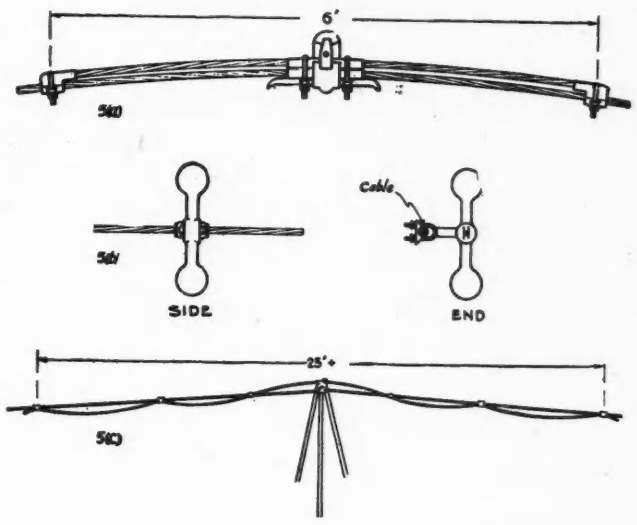


Fig. 5: (a) Conductor reinforcement on first (1927-28) construction; (b) Torsional type vibration absorber provided on one-half 1940-41 single-circuit construction; (c) Ground cable festoon used on 1940-41 construction.

higher strength has been used (26×7 strand, 795,000 cir. mils., a.c.s.r.) strung to a maximum designed tension of 12,000 lbs. Based on an ultimate strength of 30,900 lbs., the designed maximum and "60 degree" tension therefore approximate 39% and 17.6% of ultimate strength respectively.

The decision about the span used was influenced by the towers available. Had a completely new design been permitted, greater spans probably had been used. Associated with the increased span the application of vibration absorbers was decided upon, rather than the previously used armour rods. Approximately one-half of the line is equipped with the Stockbridge-damper, and one-half with the torsional damper, developed in the Commission's Laboratory and described by Tebo (Fig. 5b). Both dampers are used singly, that is, two per span. Vibration of the ground cables is protected against by the use of festoons (Fig. 5c).

**Double Circuit Construction Leaside-Burlington.**

Double circuit design has been adopted for this line in regard to the right of way cost of two single lines in the metropolitan area of Toronto. Tower design adopted is shown in Fig. 6b. Type HH, segmental, hollow-core, copper conductors, 500,000 cir. mils., 1.02 inch outside diameter, seven segments having an ultimate strength of 21,000 lbs. have been used. The ruling span is 880 feet, maximum tension 9,500 lbs., 60 degree tension 4,700 lbs. Neither precautions are taken to protect the line against conductor vibrations, nor special provisions are made in the suspension clamps and the dead-end provisions.

**Relay Protection and System Stability.**

For "phase" faults the earlier relaying consists of directional, two-stage, impedance distance relays. The instantaneous range of such relays is set to cover 85 to 90% of the line length, the overlapping second range set to cover the remainder of the line and being given a definite time delay of 0.6 to 0.8 sec. This protection effects simultaneous clearance of all faults in the mid-section of the line, but results in delayed opening of the distant breaker for end zone faults.

For "ground" faults similar protection is used, except that the relays are supplied with line residual current and phase to ground voltage and

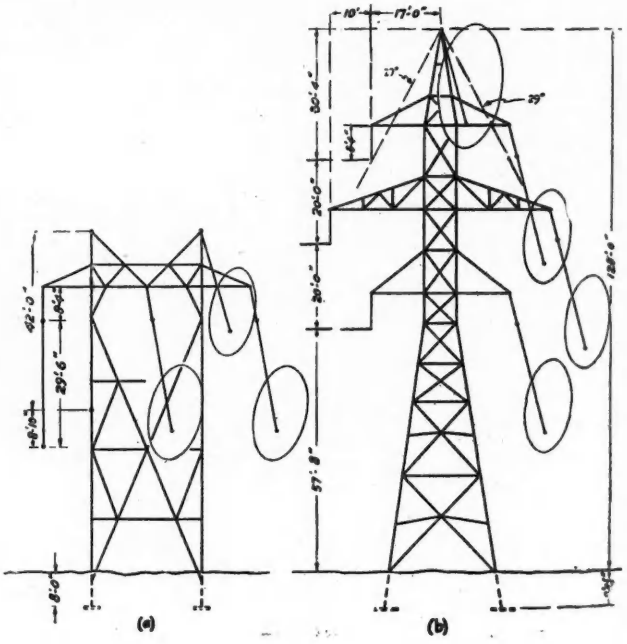


Fig. 6

(a) Clearance diagram (Lissajous figures) for 1940-41 single circuit construction. Loci based on half-loops, i.e., movement of quarter point in suspension span. Note also mid-span position of 3/4-in. ice-loaded ground cable and unloaded phase conductor.
(b) Corresponding diagram for 1941 double circuit construction. Note full loop movement of ground wires assumed at 880 ft. span.

the instantaneous range is set to cover the whole length of the line, with some margin, if the remote end is open. This results in simultaneous clearance of mid-section faults, though it also effects sequential clearance of faults in the end zones, that is clearance without the delay associated with the timed second range.

Improvements have been made from time to time in the original relaying and in the older circuit breakers, so that total clearance times now vary from 4.5 to 10 cycles, with an average of about 6 cycles (based on 25 cycles) for all faults except those cleared by the second ranges.

This protection, though admittedly below present-day standards, has nevertheless given adequate service during the building-up period on this system. Fortunately, all but very few of the 39 multi-phase faults have occurred in the high footing-resistance territory in the mid-section of the Chats Falls-Leaside lines, where this protection effects simultaneous clearance.

Improvements necessary in the protective equipment, when operating at the higher recent loadings, has been the subject of Network Calculator studies. Their results indicate, that with protective equipment effecting simultaneous clearance of all faults in 0.2 to 0.25 sec., loss of system stability at loadings of 150,000 to 170,000 kW per circuit need not be anticipated. It is proposed to attain this aim by superimposing carrier pilot control on existing and on all new two-stage impedance relaying.

## DE-GASSING OF MOLTEN ALUMINIUM-ALLOYS BY VIBRATIONS PRODUCED BY ELECTROMAGNETIC YIELDS

By TH. RUMMEL. (From the *Zeitschrift des Vereins Deutscher Ingenieure VDI*, Vol. 85, No. 24, June 14th, 1941, p. 548).

MOLTEN metals generally contain considerable quantities of gas in solution. This has the very undesirable consequence, especially with aluminium and its alloys, that cavities and pinholes are formed when the molten metal solidifies, which lower the strength and the ductility of the material.

Recently, electrically produced vibrations have been successfully applied for degassing aluminium and its alloys *).

It had been a most difficult question before, how to transmit the energy of vibrations of acoustical frequency to the molten metal. Besides the great losses of energy, which occur with the transmission, finding a body suitable to be immersed into the molten metal in order to transmit the vibrations presented a problem, a solution of which seemed not to exist. However, this difficulty has been overcome by producing the vibrations within the molten metal by electromagnetic fields.

For the experimental development of the new procedure quantities of 10 kg of molten metal were used, contained in a crucible placed within a coil according to the usual arrangement in high frequency furnaces. This coil was fed simultaneously by d.c. current producing a stationary magnetic field, and by a.c. current of medium frequency (about 1000 cycles). In the outer circuit these currents were appropriately separated. By the interaction of the static magnetic field and the high frequency currents induced in the molten metal, oscillating forces are exerted on each particle of the bath, proportional to the product of the magnetic field and the induced currents, and directed radially to (respectively from) the axis of the coil. The mechanical vibrations thus produced in the molten metal can be amplified by resonance.

It has been found possible to remove by this procedure all the gas included in molten aluminium or aluminium alloys in less than half an hour.

*See W. Esmarch, Th. Rummel and K. Beuther, Wissenschaftl. Veröffentl. Siemens-Werke, Werkstoff-Heft, Berlin, 1940.

# stripped water

In the preparation of tobacco for good quality cigarettes, the centre stem is stripped from the leaf in the manner shown above, but if this process is not carried out, tobacco including the centre stalk is uneven and contains dust which irritates the throat of the smoker. Similarly with the water required for feeding into water tube boilers it is necessary to strip from it the soluble salts and other impurities in order to secure a non-scaling, non-corrosive feed water. The Permutit "Deminrolit" Process produces a perfect stripped water from any supply without the use of heat or steam.

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# TECHNICAL NEWS

*Announcements in this section include News relating to British Firms, and on Equipment produced by British Manufacturers.*

*Available literature may be secured by addressing a request to the advertising department of "The Engineers' Digest," or by writing direct to the manufacturer and mentioning "The Engineers' Digest" as a source.*

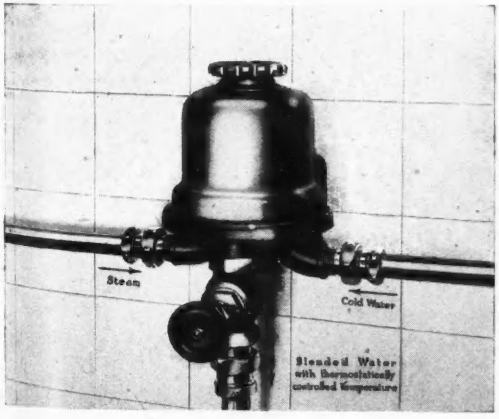

- NEW EQUIPMENT
- BOOKS AND CATALOGUES
- BUSINESS CHANGES
- PERSONAL
- NOTES


## NEW EQUIPMENT

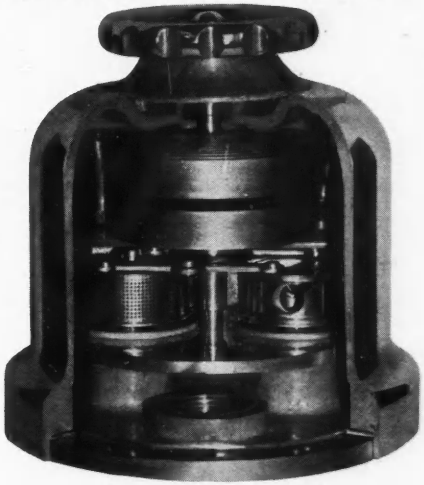
### A STEAM AND WATER MIXER WITH THERMOSTATIC CONTROL.

A NEW high capacity thermostatic steam and water mixer, known as the Leonard-Thermostatic Water Mixer, type DS, is announced by the manufacturers, Messrs. Walker, Crosweller & Co., Ltd., Cheltenham, Glos. It is for applications requiring large volumes of hot water, such as washing down and process work in factories.

The principle of operation is similar to that of the firm's well-known smaller valves, the Leonard-Thermostatic Steam and Water Mixers, types TS and RS. Steam and cold water supplies enter through twin ports into a mixing chamber containing a double coil thermostat of non-corrodible bi-metal. The temperature of the hot water at the outlet depends on the operator's requirements, and is determined by the position of a knurled handwheel on the mixer. A surge of pressure on the water supply, such as occurs when water is drawn off in another part of the building, momentarily alters the temperature of water in the mixing chamber. The thermostat being extremely sensitive to temperature changes, instantly reacts by expanding or contracting according to the nature of temperature variation. This movement is transmitted by link work to the inlet ports closing the hot and opening the cold, or vice versa. Thus, the thermostat immediately corrects the change in temperature before water reaches the outlet, and so maintains the figure set by the operator. It will be seen that large fluctuations in temperature, which are difficult to avoid when hand control is used, cannot occur with this mixer. Operation is entirely automatic, and should either supply fail the mixer cuts off delivery to a trickle. The mixer is finished in either chromium plate or polished bronze, and is conveniently fixed to a wall bracket fitting. Inlets are 1" for the steam and cold water, and the outlet is $1\frac{1}{4}$" for the blended water.




Leonard-Thermostatic Steam and Water Mixer Type "DS"



Section view of the "DS" Mixer.

### UNIT HEATERS.

UNIT HEATING is now so generally practiced that the question of which to use and whom to approach has reduced itself largely into one of selecting proved equipment embodying sound engineering theory and constructional principles.

Fewer new designs have made their appearance recently than during the immediate pre-war period. It is, however, notable that there is certainly a trend for the wider and more varied use of Unit Heaters, and there is a growing realization that Unit Heaters are not limited purely to factory heating projects.

Interesting examples are illustrated in a booklet just received from The Standard & Pochin Bros., Ltd., which goes a long way to show the range and variety of uses to which Unit Heaters may readily be applied.

Recently, greater use has been made of Electric Element Unit Heaters, and whilst not entirely new in

principle, development of design is worthy of perusal. Both interesting and novel is the form of "enclosed" electric element employed by The Standard & Pochin Bros., Ltd., in their "Calectric" Unit Heater, and it has much to commend its use, both commercially and from the engineering viewpoint.

The device embraces a structure in which the electric current-carrying wire is tightly compressed in a magnesium oxide compound and the whole embedded in a sheath of alumbro metal. The characteristic of this assembly is that magnesium oxide possesses good electrical insulating properties and at the same time is a good heat transmitter, thus allowing the generated heat to be dissipated through the metal container or sheath. Being completely sealed from contact with air, no oxidization can occur on the current-carrying wire, and, in consequence, the life of the element is considerably prolonged.

To assist in the transmission of heat and in order that the dissipated heat may be transferred rapidly to the air stream, the assembled element is fitted into "Flatfin" extended surface heating tubes, the tubes being mounted between tube plates. The assembly is then mounted into mild steel casing having adjustable louvres on the emergent side to give direction to the air flow.

In all cases the heaters are fitted with totally enclosed motors, and a special feature of note is the resilient mounting which is employed to carry the supporting arms of the motor from the back of the heater casing, this characteristic reducing vibration and drumming to a minimum.

The Standard & Pochin Bros., Ltd., will gladly furnish a copy of their booklet on request, dealing with all features relative to Unit Heater installations, whether steam, hot water or electricity is to be used as the heating medium, and contact should be made with their Head Office at Evington Valley Road, Leicester.

## CATALOGUES RECEIVED

**Micromax Telemetering and Totalizing Recorders for Electric Power.**—A new catalogue, just issued by Leeds & Northrup, shows how not only utility systems and stations, but industrial power plants and power purchasers are effecting operating economies by indicating and recording load continuously and Automatically. Well illustrated, this 28-page publication describes equipment which can telemeter over practically any distance—can totalize the load of almost any number and any combination of generators, stations, tie lines, &c. — is easily adaptable to either simple or complex requirements. To receive free copy of the catalogue, ask Leeds & Northrup Company, 4934, Stenton Ave., Philadelphia, Pa., U.S.A., for catalogue N-58-161.

**Dickrope.**—Catalogue No. 210, published by R. & J. Dick, Ltd., Greenhead, Glasgow, S.E., contains much useful information for users of Dickrope Drive. The great flexibility of Dickropes enables them to be used on small-diameter pulleys. The elasticity retained in the Dickrope allows them to deal successfully with shock loads as experienced on Compressors, Planing-machines, Fans, &c. A few illustrations of Dickrope Installations are included in the catalogue, free copy of which may be obtained upon request.

## EDITORIAL INDEX

The Editorial Index to Vol. II, January-December, 1941, has been sent to all Subscribers, together with the present issue. Binding cases for the binding of Vol. II are now available. The price is 4/6 including postage.

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